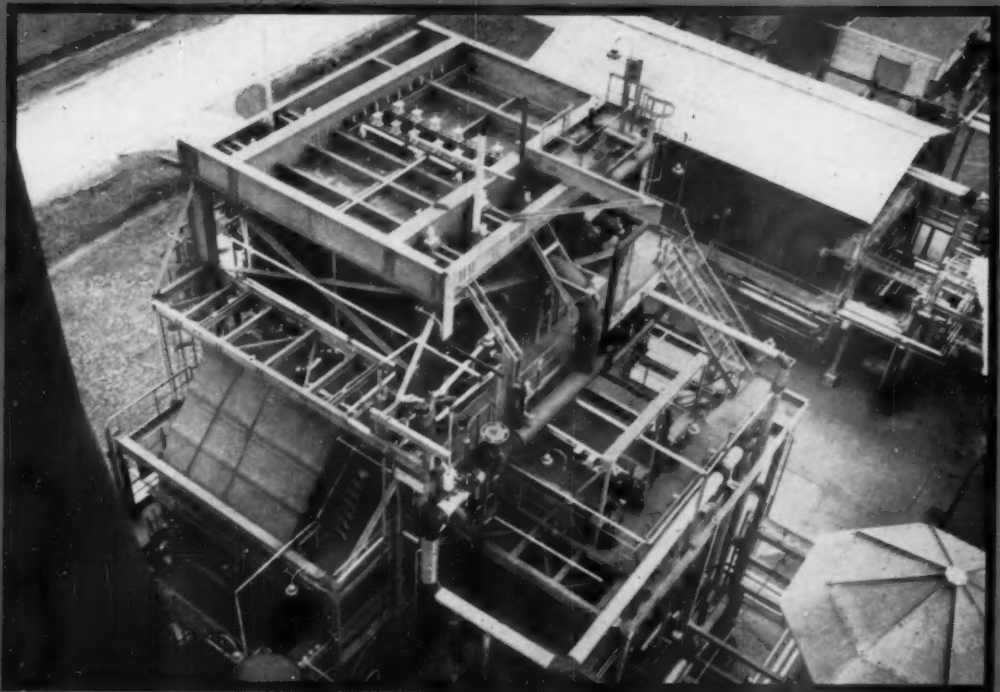
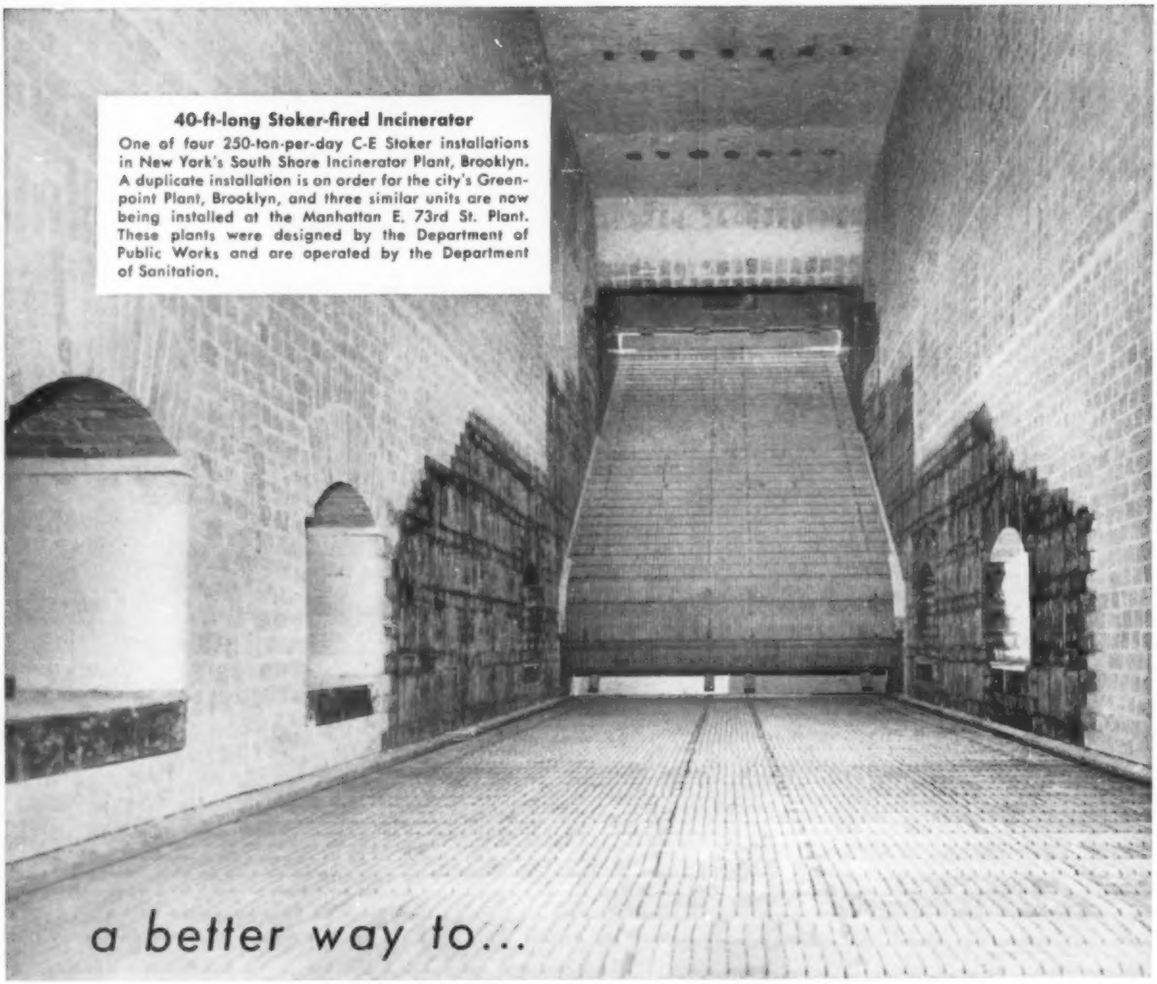
COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

May 1957



Recently installed CO Boiler at the Anacortes, Wash., refinery of the Shell Oil Co.



GET RID OF REFUSE

REFUSE – its a big problem for cities and for industries, too. Usually, the best way to get rid of it is to burn it. That's what New York City does – using enormous stokers like the two shown in the incinerator furnace above, which can burn nearly two hundred and fifty tons of garbage and all kinds of refuse a day.

Four C-E stoker-fired incinerators like this went to work in the vast New York refuse disposal system two years ago. Since then, seven similar units have been ordered.

These stokers are specially designed to meet a special problem. But stoker units like this can burn mountains of *industrial* wastes, too. Moreover, combined with a waste heat boiler, they can be used to generate steam for space heating or process work.

Other "waste" materials are also handled at a profit in C-E equipment. Bagasse – sugar cane refuse – is a thoroughly practical fuel, when it's burned in a specially-designed C-E Stoker-Boiler unit. Bark and wood chips, too, are more valuable fuels – now that Combustion has designed equipment to utilize them efficiently.

Even vast quantities of sewage sludge are dried to a saleable fertilizer, or burned to a sterile ash, in C-E Raymond Flash Drying Systems.

To handle refuse or conventional fuels . . . for disposal or steam generation . . . Combustion Engineering has both the equipment and the experience to meet any combination of requirements.

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

Vol. 28 **No. 11**

May 1957

Feature Articles

Editorials

Departments

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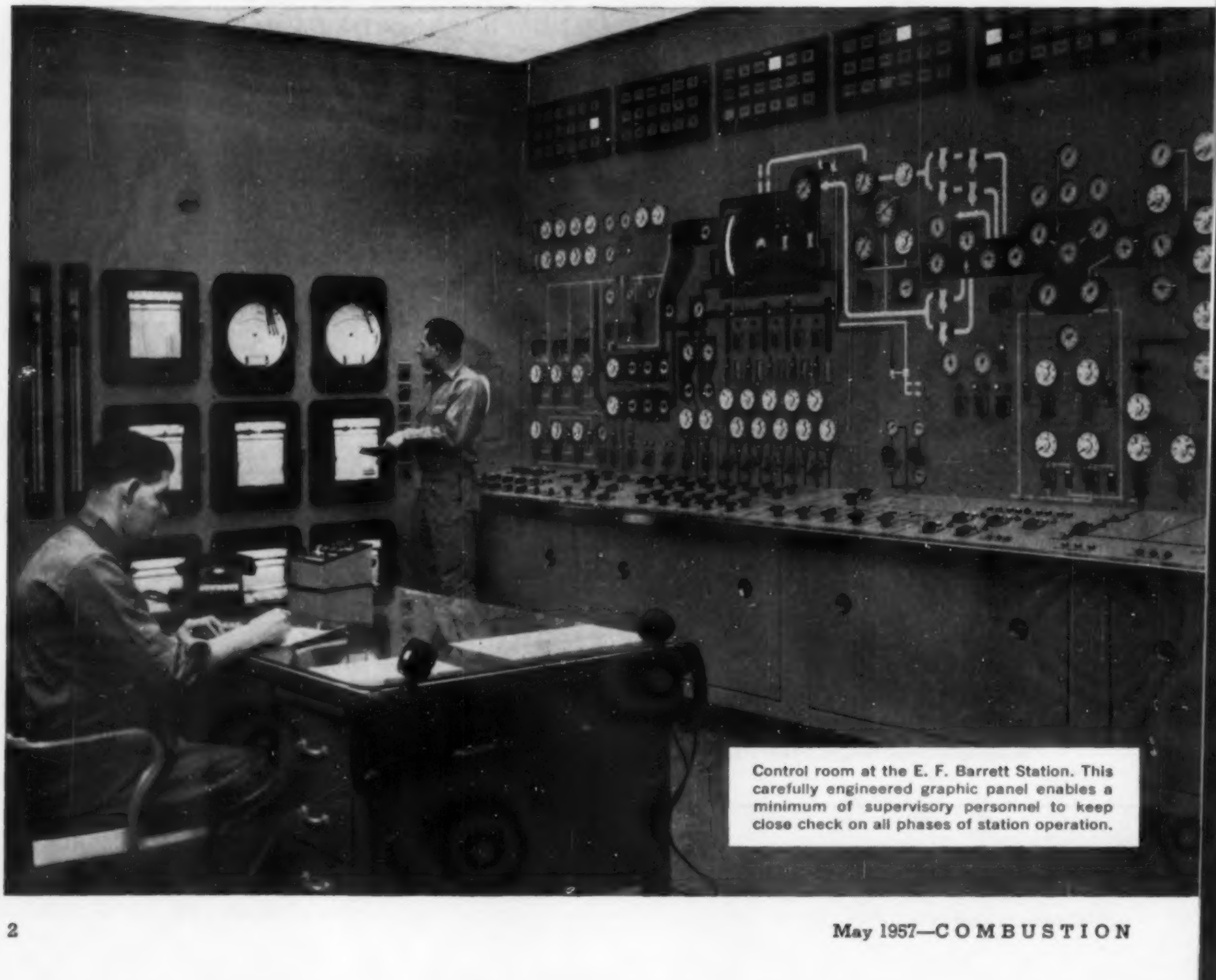
BPA

Printed in U. S. A.

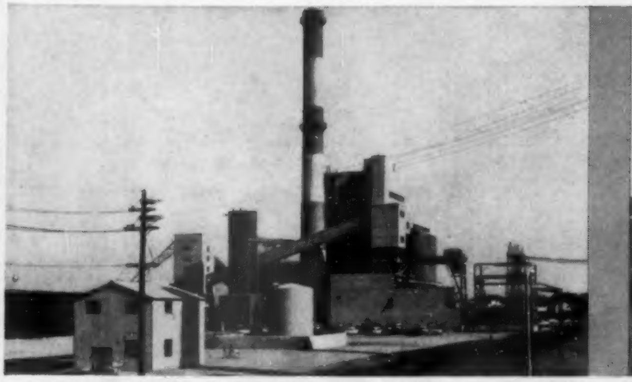
The E. F. Barrett Station, completed in 1956. This station has Hagan combustion control, three-element feedwater control, and primary metering. Designed to take full advantage of the latest construction techniques, a major part of the station is outdoors, following the pattern established at the Port Jefferson Station.

The Port Jefferson Station. Unit No. 1 (1949) has Hagan combustion control, as does Unit No. 2 (1950). Unit No. 3 will be equipped with Hagan Combustion Control, three-element feedwater control, and primary metering. The feedwater control system will include Hagan compensated drum level control.

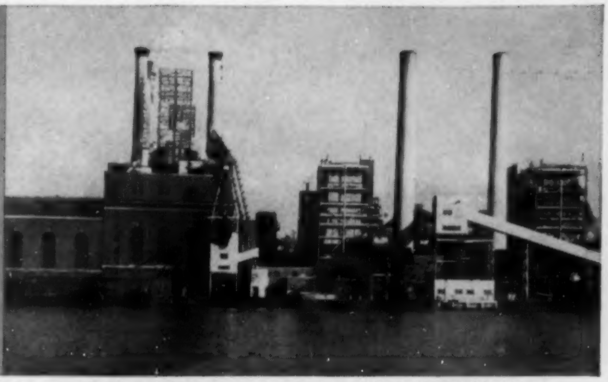
since 1942—Long Island



Control room at the E. F. Barrett Station. This carefully engineered graphic panel enables a minimum of supervisory personnel to keep close check on all phases of station operation.



Long Island Lighting Company's Station at Far Rockaway. This station went into commercial operation in 1954. It has a Hagan combustion control system. All of the stations, with the exception of Port Jefferson, are equipped with Hagan Remote Switching, providing a short direct signal path from controller to positioner.



Glenwood Station. Here Hagan has a long history. The first Hagan combustion control system was installed on Boiler #5 in 1942. Since then the record runs as follows: 1946—Boiler No. 6, 1952—Unit No. 4, 1954—Unit No. 5. Units No. 4 and No. 5 fire a combination of pulverized coal with oil or gas.

Lighting chooses HAGAN

Performance is the reason why Long Island Lighting Company now has Hagan combustion control systems on seven boilers, with an eighth on order. The last two of these are also equipped with Hagan three-element feedwater control. Management, engineers, and operating personnel alike have found that the simple, sturdy construction, high accuracy, and reliable operation of Hagan equipment contribute materially to station efficiency.

Hagan operating units perform well out-of-doors, and Hagan remote switching provides fast response to changing steam demands. Hagan three-element feedwater control includes drum level compensation which permits accurate indication and automatic control of drum level, even during start-up and shutdown.

Long Island Lighting Company is one of the nation's fastest growing utilities. The first installation of Hagan equipment was an automatic combustion control system for the #5 boiler at their Glenwood Station. On their newest unit, the very modern 180 Mw. E. F. Barrett Station, Hagan systems include automatic combustion control, three-element feedwater control, and metering.

Hagan's 39 years of experience in the design and manufacture of automatic controls for all types of boilers provide a unique background for the solution of control problems. A Hagan representative will be glad to discuss your requirements.

HAGAN CHEMICALS & CONTROLS, INC.

HAGAN BUILDING, PITTSBURGH 30, PENNSYLVANIA
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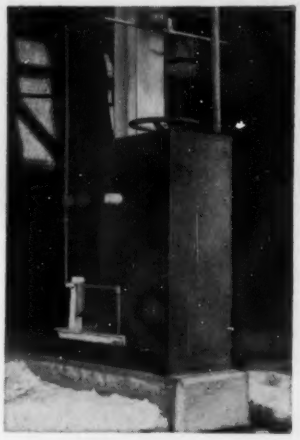
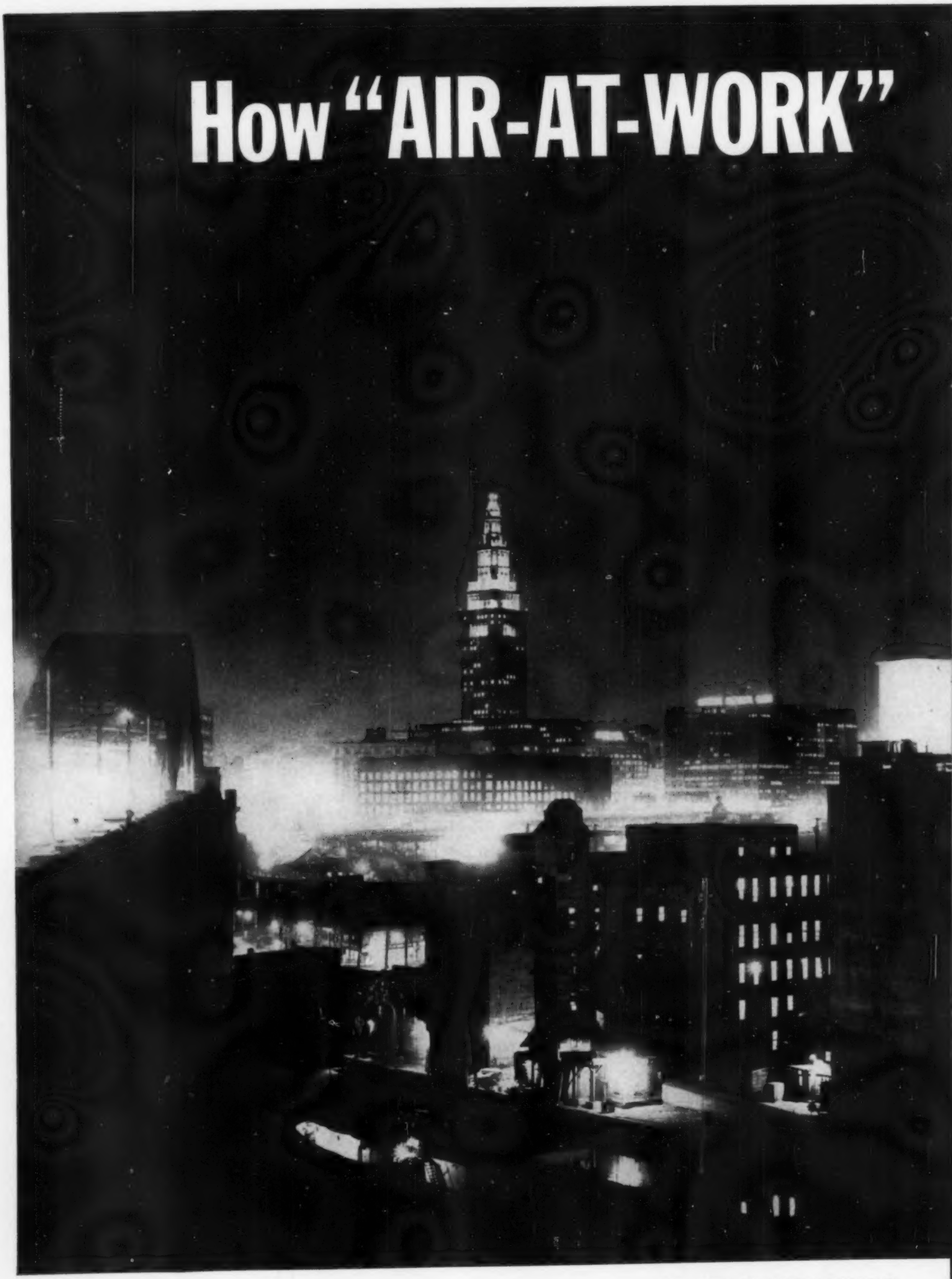


Hagan Power Positioner for induced draft fan discharge dampers. The fully-enclosed Power Positioner is designed to provide accurate, reliable positioning, whether indoors or outdoors. Station operators are particularly pleased with the integral locking feature of the Hagan Power Positioner.

How "AIR-AT-WORK"



Helps Light Cleveland

The Cleveland Electric Illuminating Company has used Westinghouse Mechanical Draft Equipment for Over 20 Years

At Cleveland Electric the job of providing combustion air for boilers is handled by Westinghouse Equipment. And in industrial plants, too, Westinghouse fans are often first choice.

The men who specify power plant equipment at leading utilities from coast to coast know that Westinghouse means top efficiency, unexcelled quality, ability to meet extremes of operating conditions—such as high volumes, high pressures, extremes of speed and temperature. Most important, they know that the Westinghouse name on air handling equipment is backed by more than 90 years' experience and leadership in design and manufacture.

For complete application service, call your nearest Sturtevant Division Sales Engineer. Or write Westinghouse Electric Corporation, Dept. 9E, Hyde Park, Boston 26, Massachusetts.

WESTINGHOUSE AIR HANDLING

YOU CAN BE SURE...IF IT'S

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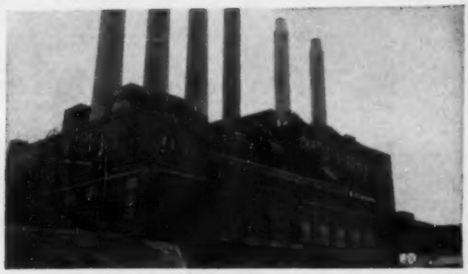
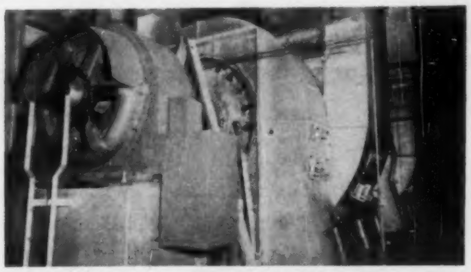
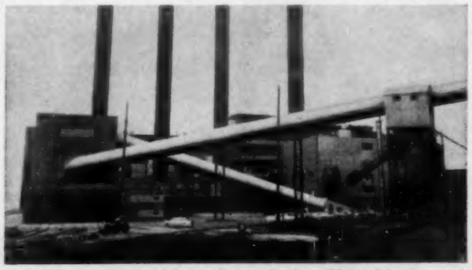


Eastlake Power Plant, The Cleveland Electric Illuminating Company, using 16 Westinghouse Heavy Duty Forced and Induced Draft Fans to provide air for 660,000 KW maximum-output generators.



Air At Work – battery of Westinghouse Heavy Duty Induced Draft fans at Eastlake. The fan motors are Westinghouse, too.



Avon Lake Power Plant, Avon Lake, Ohio. Now rated at 420,000 KW capacity, current expansion program will boost output to maximum 670,000 KW, requiring 4 more Westinghouse fans for a total of 10 FD and ID units.

Inside Avon Lake Plant, these Westinghouse Heavy Duty Induced Draft Fans are typical of Westinghouse installations throughout the Cleveland Electric system.

Electronic Route to Lower

M. W. Kellogg's Digital Computer Permits More, Faster, Accurate Flexibility Analysis of Complex Main and Reheat Piping Systems

Control section of Kellogg's electronic computer.

KEEPING PACE with the increasingly critical pressures and temperatures of the modern steam-electric power plant are M. W. Kellogg's advanced techniques for pre-determining stresses and reactions of main and reheat piping. Most recent addition is a large magnetic drum digital computer, used to calculate forces, moments, deflections, rotations, and stresses in complex piping systems.

By enabling Kellogg engineers to undertake a far greater number of calculations in less time than ever before, electronic computation makes possible the ultimate or near ultimate piping system designs. Pipe runs can often be shortened without sacrificing required margins of safety; capital investment and maintenance costs reduced; operating efficiency increased.

A pioneer in flexibility analysis techniques, which include manual calculations, model testing, and a smaller electronic computer, Kellogg continues its pioneering in the power piping industry by the addition of this high speed computer to its New York engineering facilities.

A cordial invitation to see the M. W. Kellogg electronic computer at work is extended to consulting engineers and to engineers of power generating companies and their equipment manufacturers. Appointments may be made through the Sales Manager, Fabricated Products Division.

FABRICATED PRODUCTS DIVISION

THE M. W. KELLOGG COMPANY, 711 THIRD AVENUE, NEW YORK 17, N. Y.

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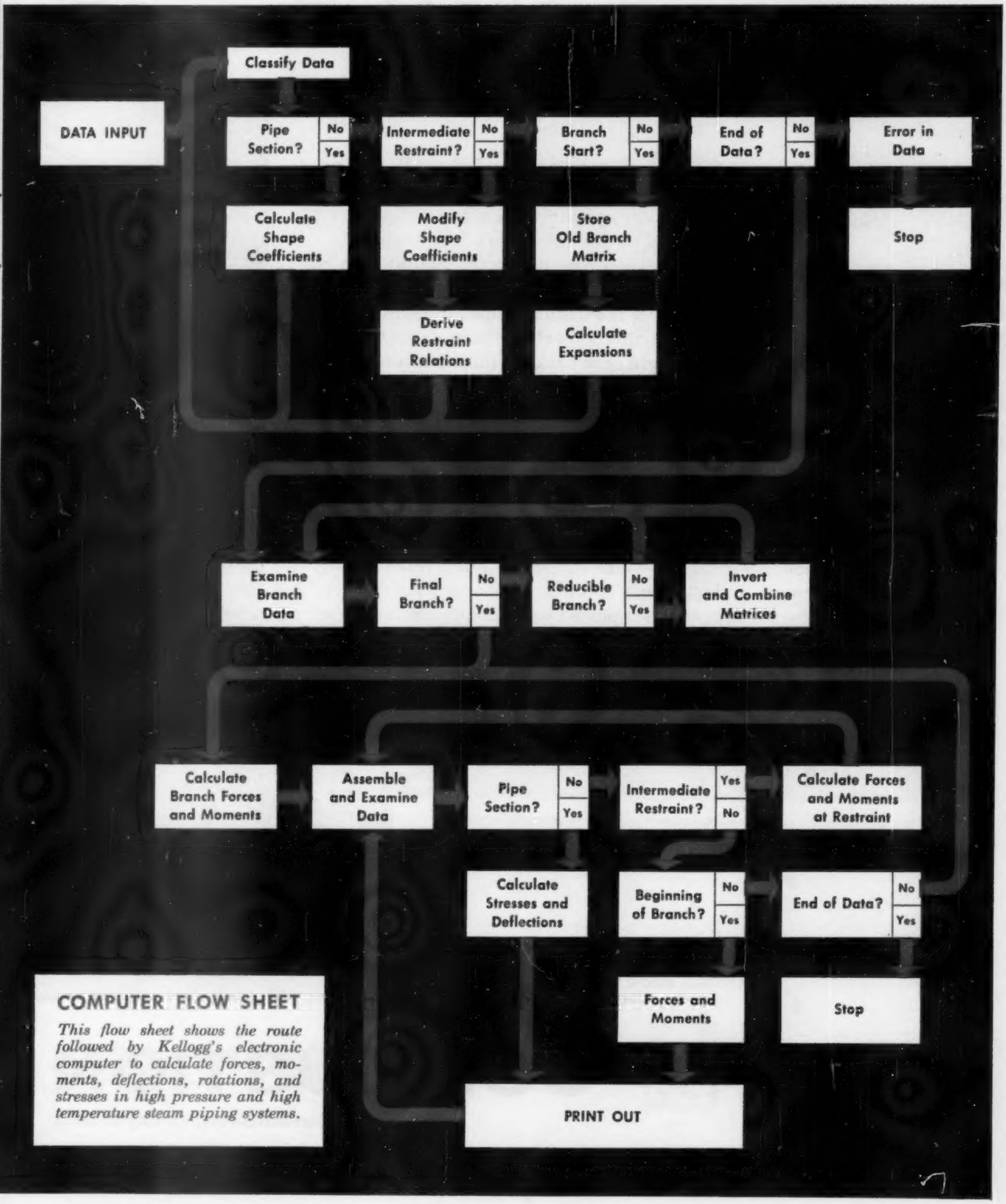
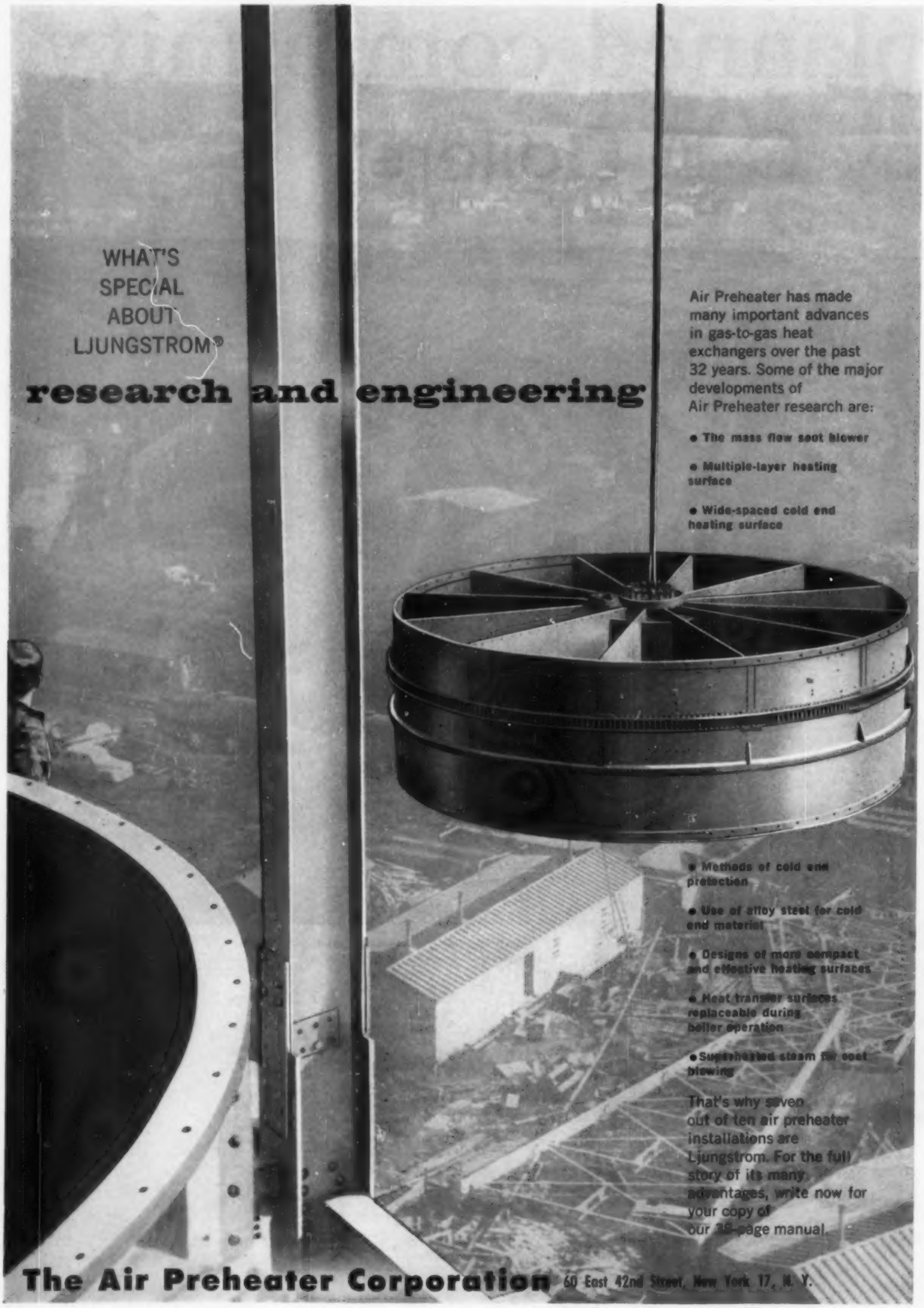
POWER PIPING—THE VITAL LINK

Steam Power Piping Costs



COMPUTER FLOW SHEET

This flow sheet shows the route followed by Kellogg's electronic computer to calculate forces, moments, deflections, rotations, and stresses in high pressure and high temperature steam piping systems.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• Designs of more compact and effective heating surfaces
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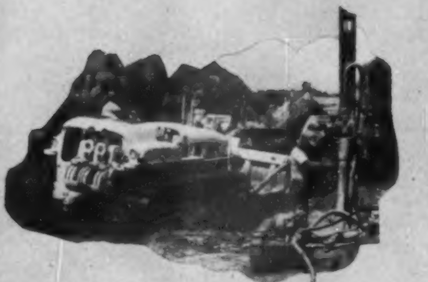
Here's why Euclid TC-12 Twin-Power Crawlers give you MORE WORK-ABILITY



PERFORMANCE

On a 200′ push at a coal mine in Pennsylvania, the TC-12 moved about 440 loose yards per hour.

On a Michigan stockpiling job, the TC-12 moved 796 tons of loose coal in one hour on a 150′ push.

On a coal strip mine operation in Ohio where waste banks had to be levelled, a TC-12 produced about 950 yards per hour with a 50′ push.

SPEED

The TC-12 has speed—up to 7.8 mph forward or reverse—but that's not all. Pivot turns (one track forward and one reverse at the same time) plus changing of direction and range under full power without loss of momentum save considerable time during the tractor's daily operation.

POWER

Two engines with a total of 436 h.p. (413 net h.p. at drive train) make this Euclid "Twin" the world's most powerful crawler. Being more powerful, the TC-12 offers additional benefits, such as faster work and longer engine life, since the engine often operates at less than full capacity without strain. And, the reserve power permits handling the toughest tractor job.

MANEUVERABILITY

Pivot turns with the TC-12 take less space and time. Changing directions on the go with Torqmatic Drives makes maneuvering into position quicker. Split-half construction gives better traction on uneven ground.

EASY OPERATION

Clutching and shifting are eliminated with the TC-12 "Twin". There's 24-volt push-button starting and instant response to directional levers, range selector and hand throttle levers, all of which are conveniently located to allow complete freedom of the operator's right hand for control of attachments.

DESIGNED FOR EASY SERVICING

Many design features contribute to long life and easy servicing. Location of radiator behind operator reduces damage and improves cooling. Track tensioning and recoil system are automatic. All engine accessories are readily accessible from outside the engine compartment. Rollers can be removed without breaking track. Engines, Torqmatic Drives, and planetary final drives can be removed without disturbing the other components.

**THEY ALL ADD UP to just one thing—
Euclids are your best investment.**

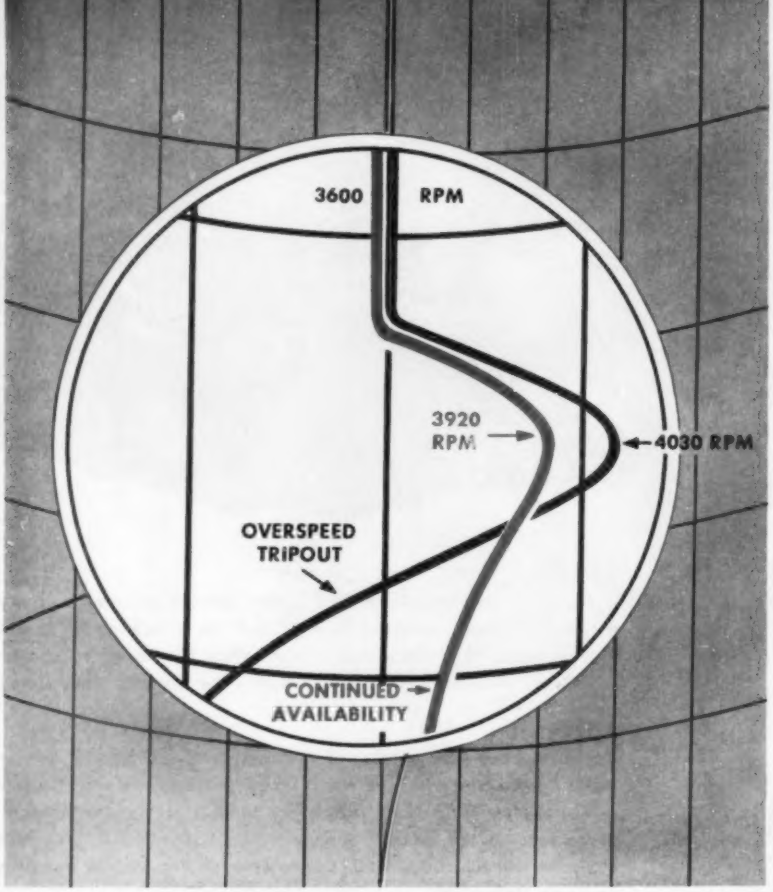
EUCLID DIVISION,
GENERAL MOTORS CORPORATION, Cleveland, 17, Ohio

EUCLID

Euclid Equipment

GM
MORE POWER FOR YOU

FOR MOVING EARTH, ROCK, COAL AND ORE

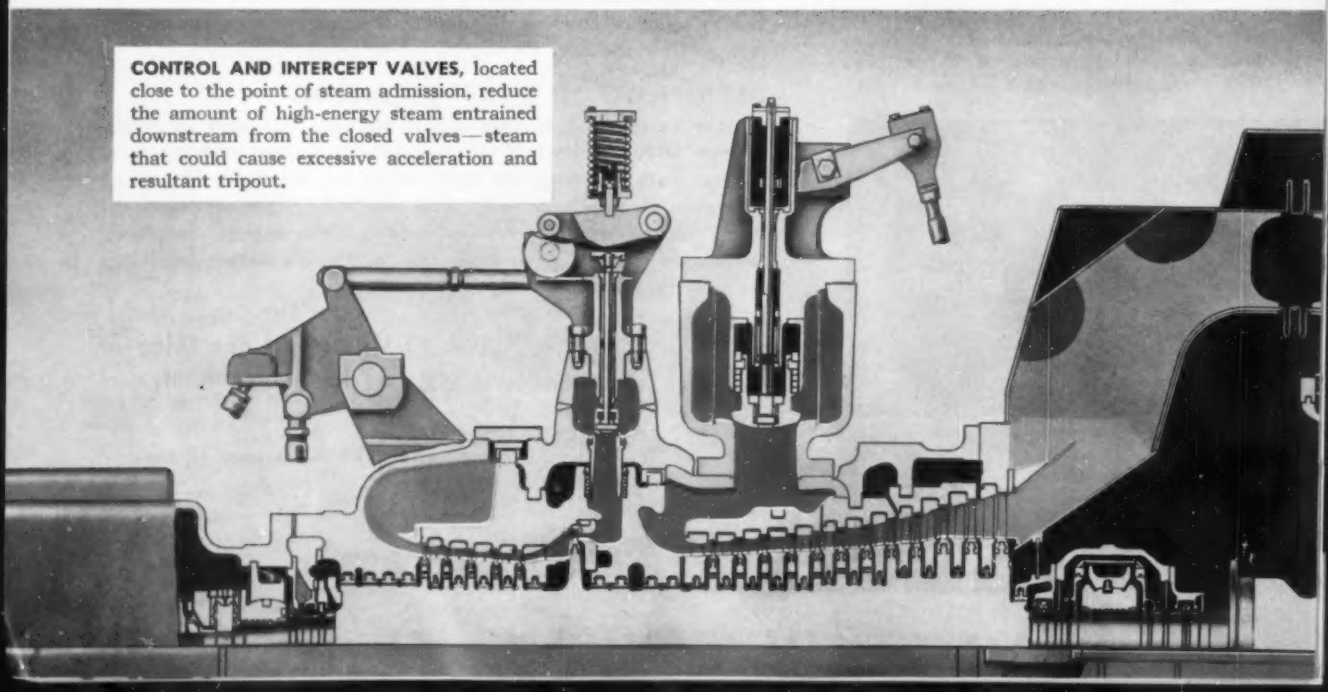


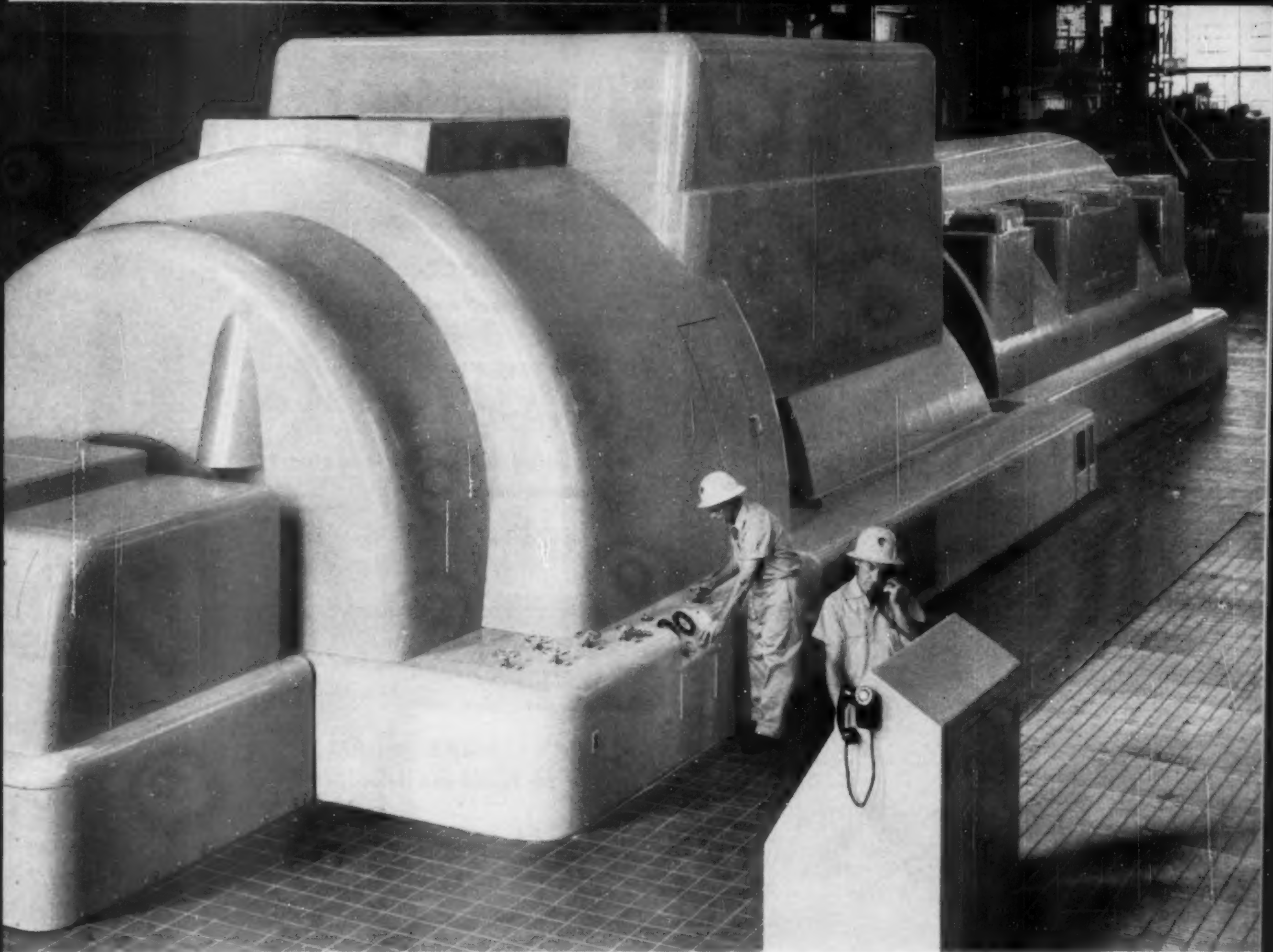
SENSITIVE GOVERNING SYSTEM helps avoid costly tripouts. The red curve, above, shows how a typical G-E reheat turbine stays below tripout speed by limiting speed to 3920 rpm during temporary system interruption. Without this split-second governing response, overspeed to 4030 rpm can result in costly shutdown.

SPLIT-SECOND RESPONSE to system disturbances helps keep units like this on-the-line. Pictured here is a 150,000 kw reheat steam turbine-generator at Oklahoma Gas and Electric Company's Riverbank Station.

Split-second response helps keep

CONTROL AND INTERCEPT VALVES, located close to the point of steam admission, reduce the amount of high-energy steam entrained downstream from the closed valves—steam that could cause excessive acceleration and resultant tripout.





General Electric turbines on-the-line

SENSITIVE GOVERNING SYSTEM COPES WITH TEMPORARY SYSTEM DISTURBANCES

Requirements for sensitive, faster-responding governing systems have steadily increased with the trend toward larger reheat turbines with their inherent high overspeed potential.

Modern turbines entrain significant quantities of high-energy steam downstream from control and intercept valves and in crossover pipes. Because this steam can cause rapid acceleration upon load loss, governing systems must instantly sense speed changes to ride through temporary system disturbances. A split-second time lag may mean the difference between tripout and continued turbine availability.

Locating control and intercept valves as close as possible to the turbine operating stages reduces the amount of high-energy steam trapped downstream from the valves. With the acceleration potential of this entrained steam kept to a minimum, overspeed is limited and the turbine remains on governor control despite temporary system interruptions.

Other refinements such as use of an extremely sensitive governor and relays help make fast response possible. This governor senses the slightest change in speed and transmits a signal to activate the governing system.

Sensitive response of governing systems is another example of how General Electric turbine research and engineering leadership combine to build tomorrow's turbine-generators today. For further information on reheat turbine overspeed protection, write for bulletin GER-920, Large Steam Turbine-Generator Department, General Electric Company, Schenectady 5, New York. 254-39

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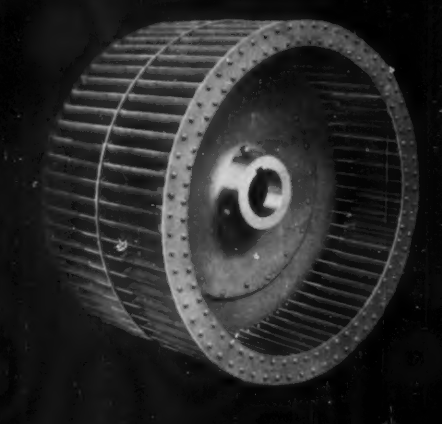
American Blower Fan Wheels

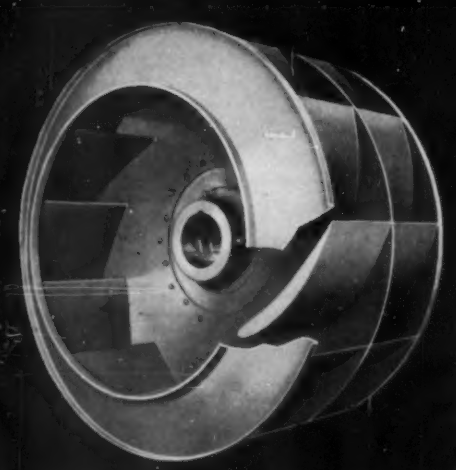


SIROCCO WHEELS
for forced and induced draft duty

- For balanced draft or pressurized furnace
- Low tip speed
- Die-formed, forwardly inclined blades and heavy streamline inlets
- Used in power plants the world over

AHS WHEELS
for forced and induced draft duty

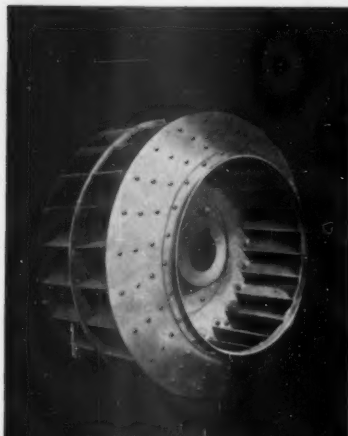
- Backwardly inclined, nonoverloading horsepower characteristic
- For given duty operates at higher R.P.M.
- Single thickness flat or curved blade
- Heavy rolled streamline inlets



AIRFOIL BLADE WHEELS
primarily for forced draft duty

- Blades are of airfoil cross section, die formed and reinforced as required
- High mechanical and static efficiency
- Nonoverloading power characteristic
- Available with vanes and/or boxes

Meet Peak Efficiency Standards



Radial tip blade wheel

RADIAL BLADE WHEELS

for forced, induced and gas recirculating duties

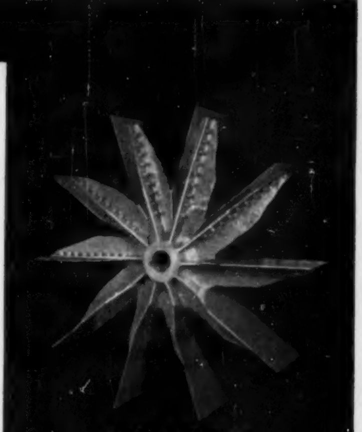
- Pressure characteristic favorable to gas recirculating application where unusual system pressures prevail
- Designed for severe temperature and pressure duty
- Available with straight radial or radial tip blades

Straight radial blade wheel

Rim type wheel for primary air fans

SINGLE INLET RADIAL BLADE WHEELS FOR PRIMARY AIR, VENT, AND OVER FIRE DUTY

- Designed for high temperature, high pressure applications
- Radial or backwardly inclined blades, single inlet
- Over 1200 primary air fans in operation



Rimless wheel for vent and over fire fans

IF YOUR plans include mechanical-draft equipment—for new installations or as replacements—consult your American Blower sales engineer. He can give you helpful information on job-fitted American Blower equipment to meet your power-plant requirements. Call our nearest branch office or write: American Blower Division of American-Standard, Detroit 32, Michigan. In Canada: Canadian Sirocco products, Windsor, Ont.

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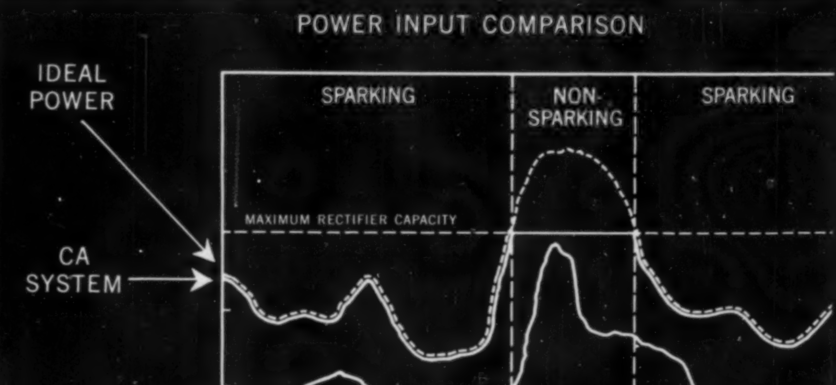
RESEARCH-COTTRELL'S
New C A System brings Auto to precipitators



Higher "around-the-clock" collection efficiency without any manual adjustments. That sums up the major advantages of Research's new Cottrell Automation System.

The chart at the left shows how the CA System provides these advantages. As you know, ideal electrical power input to a precipitator is not constant. It varies with changes in gas composition, temperature, rate of flow and humidity, as well as characteristics of the dust, such as size, electrical resistivity and extent of build-up on the electrodes. With conventional controls, manual adjustments cannot keep pace with these changing conditions. This difference between *ideal* electrical power and *actual* power input, under manual control, is shown in the chart. This

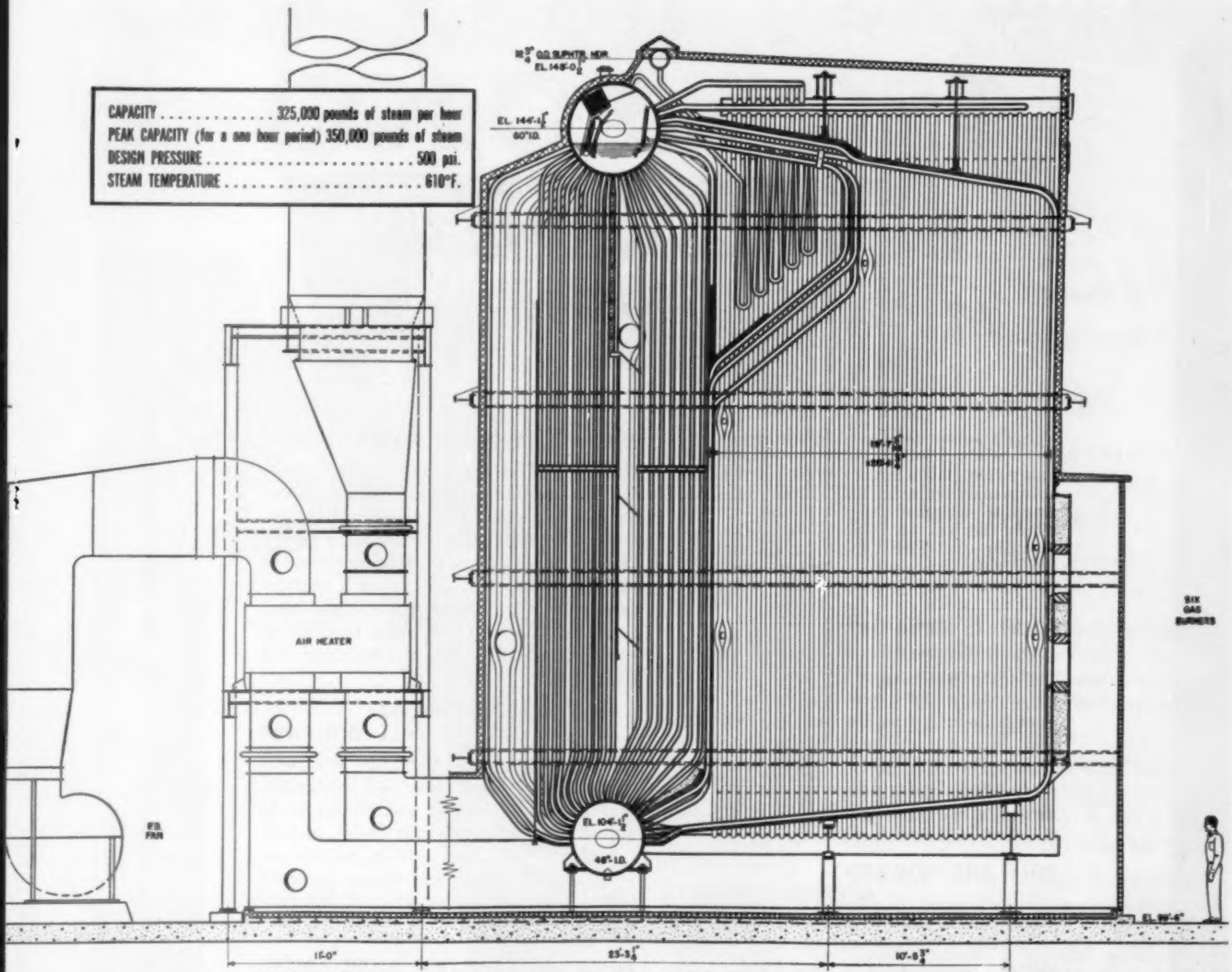
mation

difference means lower collection efficiency. The fast acting electronic circuits of the CA System provide the best practical approach to ideal electrical power. During periods of sparking, electrical power input is controlled by the optimum sparking rate, which can be easily pre-set to any value between 0 and 500 sparks per minute. Under some conditions power input would have to be increased beyond the capacity of the electrical equipment in order to maintain this optimum sparking rate. During such periods the power input is governed by the *capacity* of the electrical equipment. This condition is shown in the center vertical section of the chart. For more information on this new automation development write for your copy of Bulletin CA. It has a detailed description of how the Cottrell Automation System works and how higher "around-the-clock" collection efficiencies and lower operating costs are obtained.

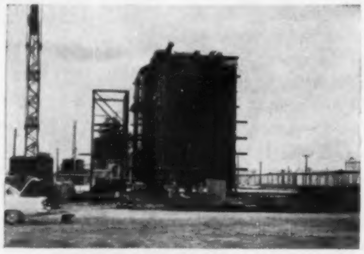
Research-Cottrell

RESEARCH-COTTRELL, INC., Main Office and Plant: Bound Brook, New Jersey • 405 Lexington Ave., New York 17, N. Y. Grant Building, Pittsburgh 19, Penna. • 228 No. La Salle St., Chicago 1, Ill. • 58 Sutter Street, San Francisco 4, Cal.

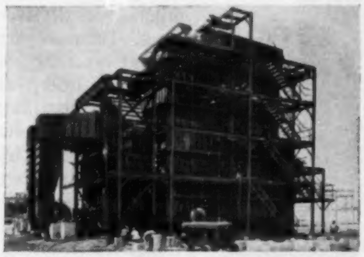
RC172



HEADER WITH PRE-ASSEMBLED TUBING is quickly and efficiently raised into position by crane used for building construction. Beyond savings in time, this technique makes top quality of completed unit easier to achieve.



FINAL STAGES OF ERECTION include a careful inspection. Republic ELECTRUNITE Boiler Tubes provide maximum reliability throughout every length. There are no hidden thin spots to threaten service life or cause uneven heat transfer.



JACKET INSTALLED, Riley Steam Generator is virtually complete. Republic offers a handy guide outlining proper protection of boiler installations. Send coupon for wall chart entitled "Care and Maintenance of Boiler Tubing", today.

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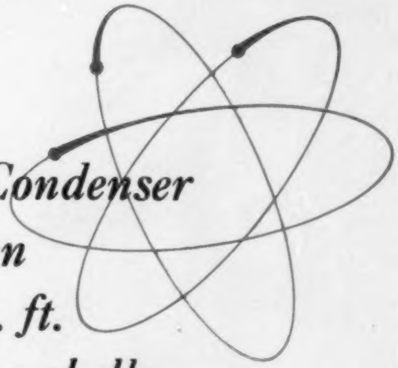
Surface Condenser

NUCLEAR POWER PLANT



Advanced design I-R Condenser for Indian Point Station will contain 212,000 sq. ft. of cooling surface in two shells

SCHEDULED for completion in 1960, the Indian Point Nuclear Station of Consolidated Edison Company of New York, Inc., will pioneer many inovations in power plant equipment and design.

The I-R twin shell condenser serving the 275,000-kw turbo-generator unit will be the largest on the Con Edison system. The turbine is an 1800-rpm single shaft, double exhaust unit, and the condenser size is comparable to that of a unit serving a conventional 400,000-kw turbine. The two condenser shells will contain almost 180 miles of tubing with a total condensing surface of 212,000 sq ft. The 31,508 tubes will be welded at both ends into silicon-bronze tube sheets. Special hotwell trays will be provided with a total of 24 sampling connections to permit continuous indication of condensate purity.

Ingersoll-Rand will also supply the boiler-feed pumps, circulating pumps and steam-jet ejectors for the history-making Indian Point Station. The three specially-designed boiler-feed pumps will have a capacity of 2425 gpm at 632-psig discharge. And the two huge vertical circulating pumps will each handle 140,000 gallons per minute.

This outstanding installation is further evidence of Ingersoll-Rand's ability to meet *any* surface condenser requirements for any turbine-condenser arrangement. Your I-R engineer will be glad to discuss your power plant problems and help you determine the equipment best suited to your needs.

IR Ingersoll-Rand

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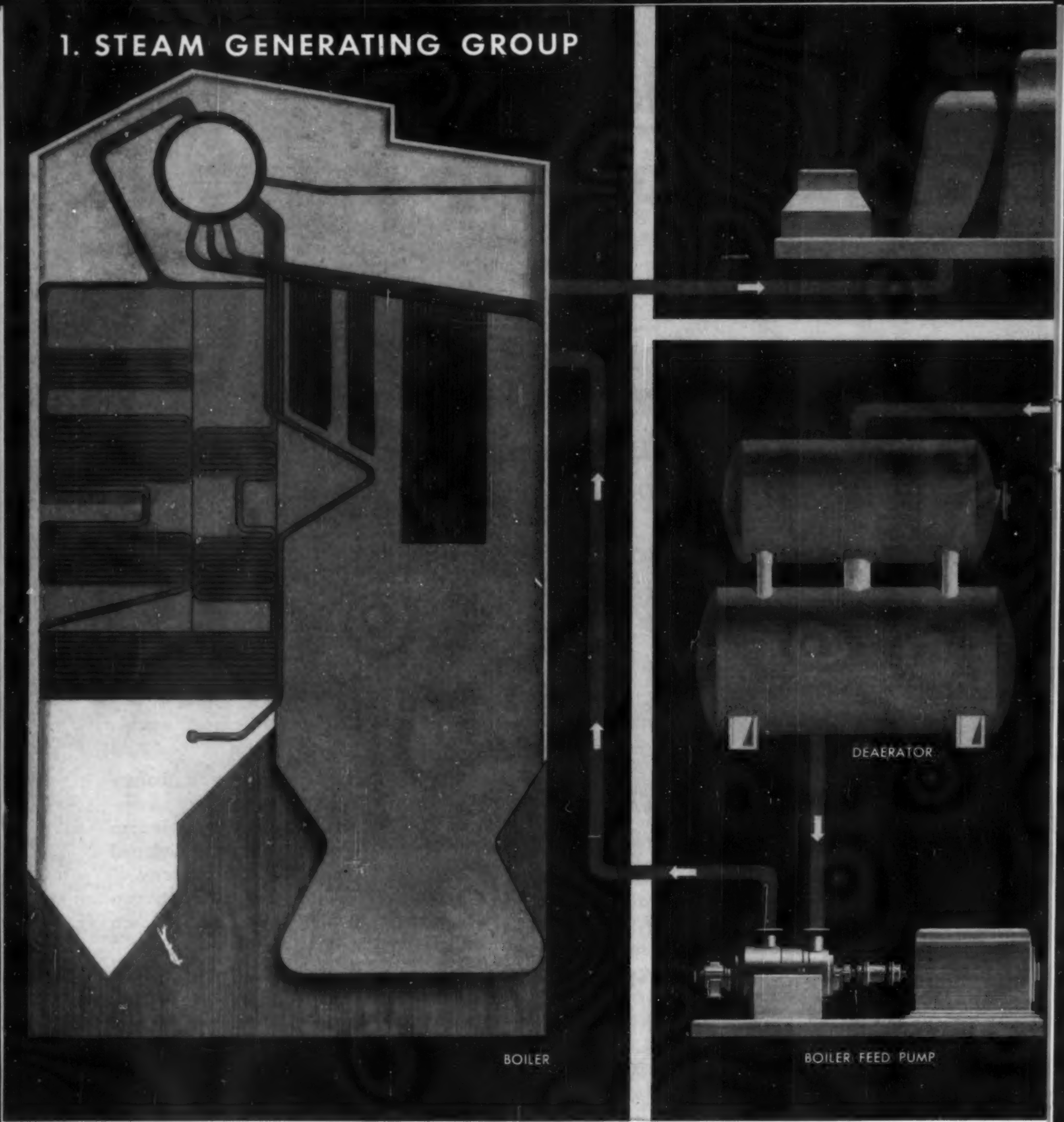
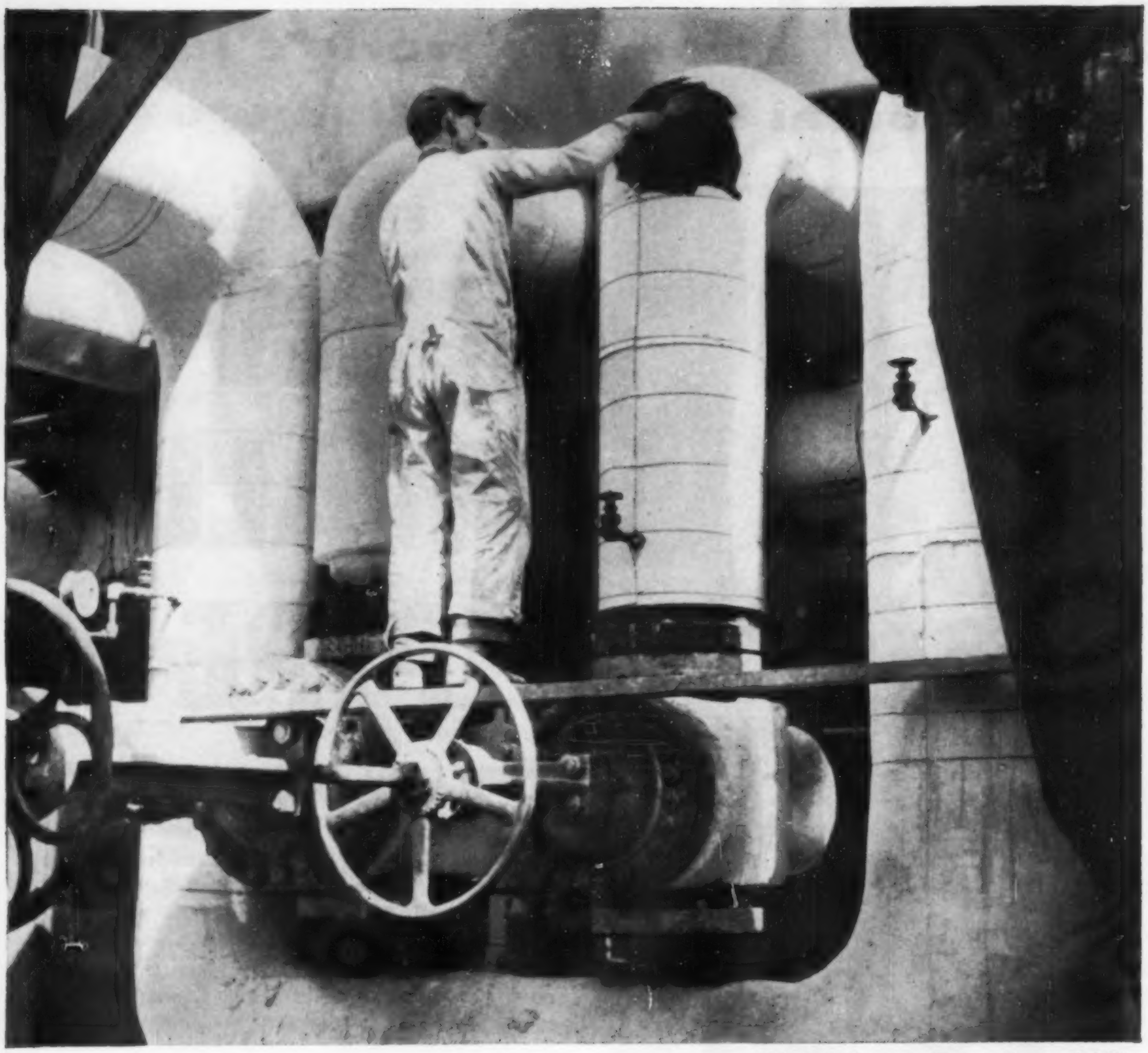


Look at all three

A new steam station design approach is bringing higher efficiencies, lower costs, and greater reliability. In this approach, only three basic functions are considered: (1) Steam Generating, (2) Electric Generating. (3) Fluid Handling. Station requirements are first analyzed in terms of the over-all job performed by each of these groups rather than by each individual piece of equipment.

Many of the benefits of this approach occur in the Fluid Handling Group. Here coordination and integration of the wide variety of equipment used can often effect substantial improvement in over-all operation. As steam temperatures and pressures go up, there are increased demands on the fluid handling function. Plant reliability often depends on the effect of one component of the fluid handling group on another during operational transients, either planned or of emergency nature. The solution is coordinated equipment



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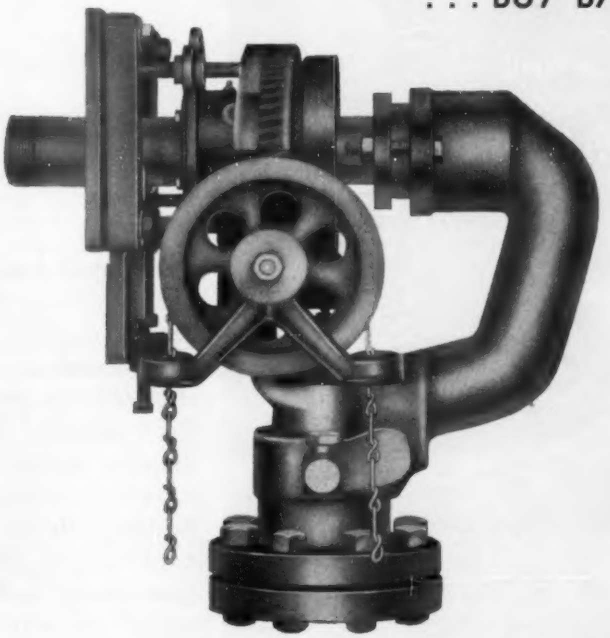

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COMBUSTION

Editorial

America's Next Twenty Years

Predicting what will happen in the future is a hazardous occupation, even under the most favorable circumstances. But if one is willing to accept a trend, such as the birth rate, and to assume that no countertrend will arise, then it is reasonably safe to make predictions. This is what Peter Drucker has done in a recent book (Harper, $2.75) having the same title as this editorial.

Based on studies of the birth rates for the past quarter century, Mr. Drucker comes to the conclusion that America will face a labor shortage, rather than a labor surplus, during the next twenty years. To meet this labor shortage it will be necessary to accelerate the use of automation, and Mr. Drucker cites the electric power generating industry as an example where the numbers of relatively unskilled operating personnel have been greatly reduced.

Herein lies a paradox that may be overlooked. In the laudable desire to reduce power plant manpower, insufficient attention is sometimes given to the capitalized costs of centralized control and the wage differentials between relatively unskilled operators and highly trained technical personnel required to operate an almost fully automated power station. What is the ultimate in this trend? Is it the utility company with a centralized computation and dispatching center at its general offices automatically operating a group of power plants without operators and sending out maintenance crews only when an automatic data logger indicates potential trouble in a particular plant? Or is it possible that the sum of operating labor costs plus amortized capital costs already indicates that some power plants may have moved farther in the direction of automation and complete centralized control than is economically justifiable? Wherein lies the optimum point of minimum costs and most effective use of the labor force?

These are all questions that must be faced sooner or later by those who design, own or operate power plants. If Mr. Drucker is right and labor shortages become acute, then the trend toward automation, even in the power industry which has the advantage of long experience and an early start, will be greatly accelerated. But if Mr. Drucker is wrong, and should the wage differentials between skilled and unskilled personnel change markedly, then another look should be taken at the economics of centralized operation of power plants.

Putting A Shoulder to the Wheel

The Eddystone supercritical cycle conveys a rather special excitement to the mind of the average power engineer. The pressure and temperature levels involved made a review and a reappraisal of the entire philosophy behind present day power plant design imperative. At the Second Annual Power Forum, April 23, 24, of the Philadelphia section ASME, co-sponsored this year by the Pennsylvania Electric Assn., this review and reappraisal was presented from the viewpoint of the major manufacturers involved and certain of the Philadelphia Electric Co. principals. This approach resulted in an impressive meeting.

But above and beyond the stimulation those in attendance drew from the individual accounts of problems faced and solutions attempted must have been one of strong admiration for the overall planning and cooperative spirit underlying the entire project. **K. M. Irwin,** vice president, engineering department of Philadelphia Electric Co., in the banquet address brought this point out quite clearly. He mentioned several cooperative supplier and purchaser research studies being conducted for better understanding and better equipment development. These he felt vital to the success of the entire project.

Unquestionably it is only prudent for the manufacturer to sponsor and promote research leading towards orderly product development. But major breakthroughs that can catapult an entire industry's thinking beyond the level expected from the gradual advances of conventional practice to conditions imposing sharply new approaches and operating techniques require a community of participants; the old saw of everybody putting his shoulder to the wheel. Circumstances usually work against such concerted action. The papers at Philadelphia, with their free admission by the participants of a dependence upon one another, and the announced employment of a committee structure to promote an open exchange of progress reports bore testimony to the workability of such concerted action. Eddystone may well prove to be a milestone in the advancement of development techniques as well as in thermodynamic cycles.

The gas turbine has indicated promise of operating flexibility ever since its inception. Today these promises have been applied to power and process cycles. This paper classifies the principal methods of combining steam and process with the gas turbine and points out certain of the boiler considerations involved in selecting particular methods.

Gas Turbine Boiler Applications[*]

By HENRY J. BLASKOWSKI and JOSEPH G. SINGER

Combustion Engineering, Inc.

A GAS turbine can be incorporated into a steam power plant in ways that yield widely differing results. The questions of deciding how to combine the two and of deciding what percentage of the total power output is to be generated by each are for the consulting engineer to resolve with the assistance of turbine and boiler manufacturers. Although the combined efforts of all three are required for an efficient solution, the functions and responsibilities of each are different. This paper reviews the problems presented to the boiler designer and describes some of the more recent solutions.

The engineering approaches to the analysis of gas-steam cycles result in arrangements that fall into four general classifications. These are: (1) unfired heat recovery and steam generating systems; (2) fired heat recovery and steam generating systems; (3) supercharged systems; and (4) closed cycles.

Unfired Heat Recovery

The first classification breaks down into two types. One of these covers the general situation in which the gas turbine exhaust passes over an economizer or stack gas cooler, which functions as a feedwater heater by raising the temperature of the condensate in a regenerative steam cycle. This arrangement has been suggested in areas where rapid provisions for the handling of peak loads have been found necessary. Under peak load conditions, the gas turbine is fired and its products are exhausted to the stack cooler. The condensate circulated through the stack cooler is bypassed around one of the feedwater heaters. The extraction steam oridinarily required for this feedwater heater is then made available to the turbine. This arrangement permits the heat recovered from the gas turbine exhaust to be converted into additional power without the increased cost of steam generating equipment.

Fig. 1 illustrates the equipment required for the application of a 25,000 kw gas turbine to peak a steam cycle presently capable of generating 215,000 kw. The existing steam generating unit has a maximum evaporation of 1,470,000 lbs per hr and operates at 2400 psig at the superheater outlet. It has a primary steam temperature of 1050 F with reheat to 1000 F The stack gas cooler proposed substitutes for the two heaters used in the regenerative cycle, receiving the full feedwater flow and heating it from 353 F to 452 F. The gas turbine exhaust flow of 1,700,000 lbs per hr enters the feedwater heater at 850 F and leaves at 490 F. The feedwater heater and connecting ductwork impose a 10-in. w.g. backpressure on the gas turbine. Although this gas turbine generates 25,000 kw, a net gain of approximately 37,000 kw can be appreciated from the combined plant. The additional flow through the steam turbine, which increases its output by 12,000 kw, accounts for the difference.

Another example of this type of application is shown schematically in Fig. 2, where two gas turbine-driven generators were added to a system having two steam-driven generators. Here the approach was somewhat different. The steam cycle contained only single low-pressure heaters capable of raising the condensate temperature to 185 F. Recuperative feedwater heaters were installed, each of which recovers 40 million Btu per hour from the gas turbine exhaust, raising the temperature of the water to the boilers to 295 F. The effect of the addition of the feedheaters following each of the gas turbine power plants was to increase both the overall station efficiency and the capability of the steam cycle. Fig. 3 shows the two Combustion Engineering recuperators located outside the gas turbine room.

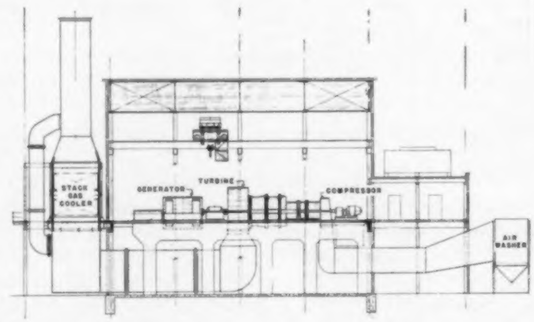

Fig. 1—Application of a 25,000-kw gas turbine for peaking service permits using a stack cooler in the path of its exhaust to serve for feedwater heating

* Presented by Mr. Blaskowski, November 16, 1956, at the Boiler-Turbine Seminar, El Instituto Technologico y de Estudios Superiores de Monterrey, Mexico.

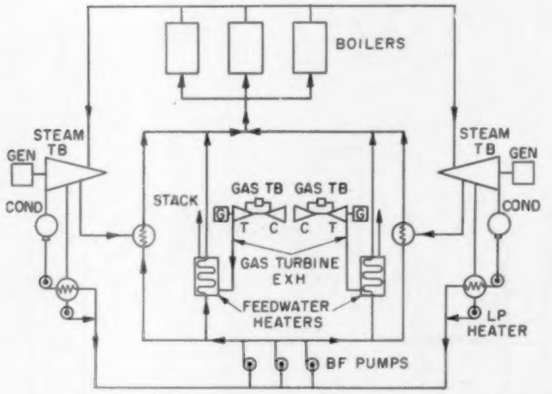

Fig. 2—Diagram shows gas turbine exhaust heat recovery cycle for steam plant feedwater heating

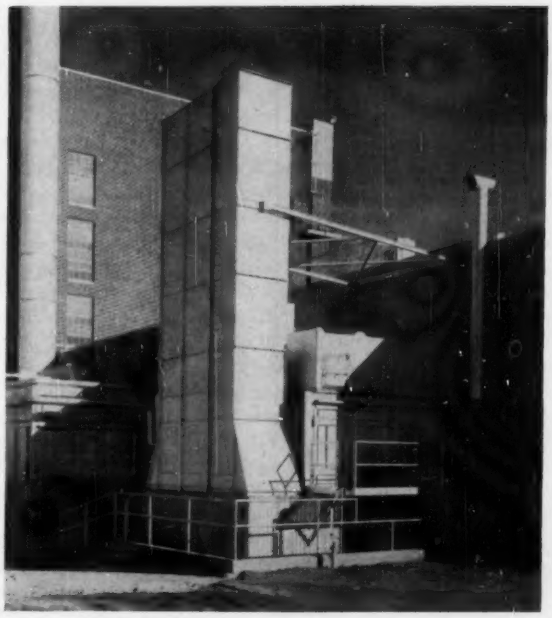

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Fig. 3—Two recuperators in schematic, Fig. 2, are located outside building and each recovers 40 million Btu per hr.

The other method for handling this unfired recovery problem is to generate steam from the turbine exhaust gas in a waste heat boiler. This is an arrangement that has been suggested at various times for the making of steam for process, power, and heating. Fig. 4 illustrates a simple design for such use. Since no means of firing fuel in this boiler is provided, the steam output is nearly directly proportional to the gas turbine electrical output, as shown in Fig. 5. It is characteristic of the simple-cycle single-shaft gas turbine usually considered for this application that it produces substantially the same quantity of exhaust gas at all loads, but with sharply dropping exhaust temperature as kilowatt output decreases. A superheater installed in such a boiler also has a dropping characteristic. The usefulness of this scheme depends upon the desirability of having a steam generating unit in which the evaporation rate and steam temperature are direct variables of gas turbine output.

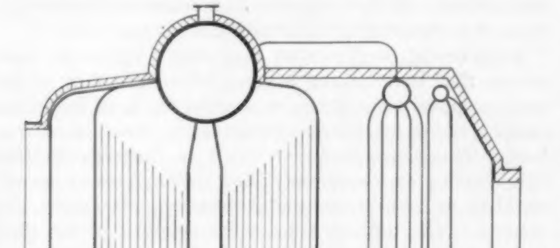

Fig. 4—Waste heat boiler for 35,000 lb per hr evaporation employing the exhaust from a 5000-kw gas turbine, above

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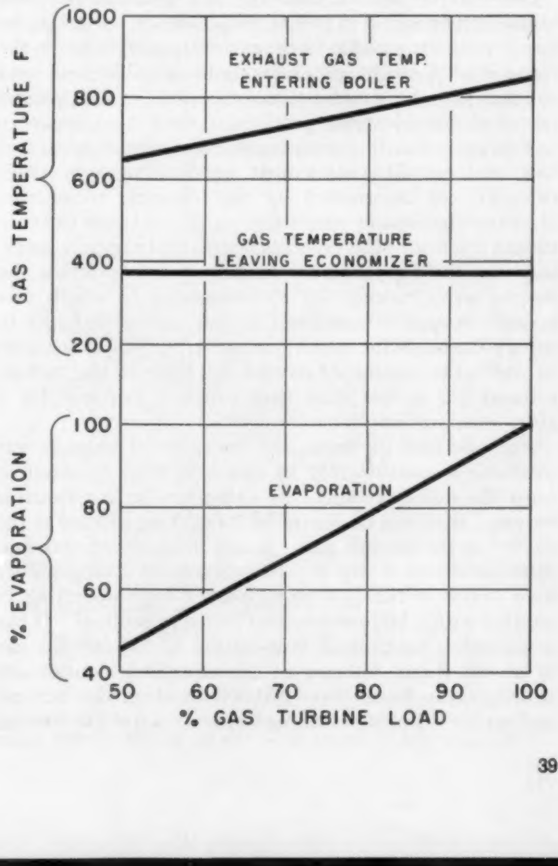
Fig. 5—Characteristic performance curves of waste heat boiler for simple cycle, single-shaft gas turbine, right



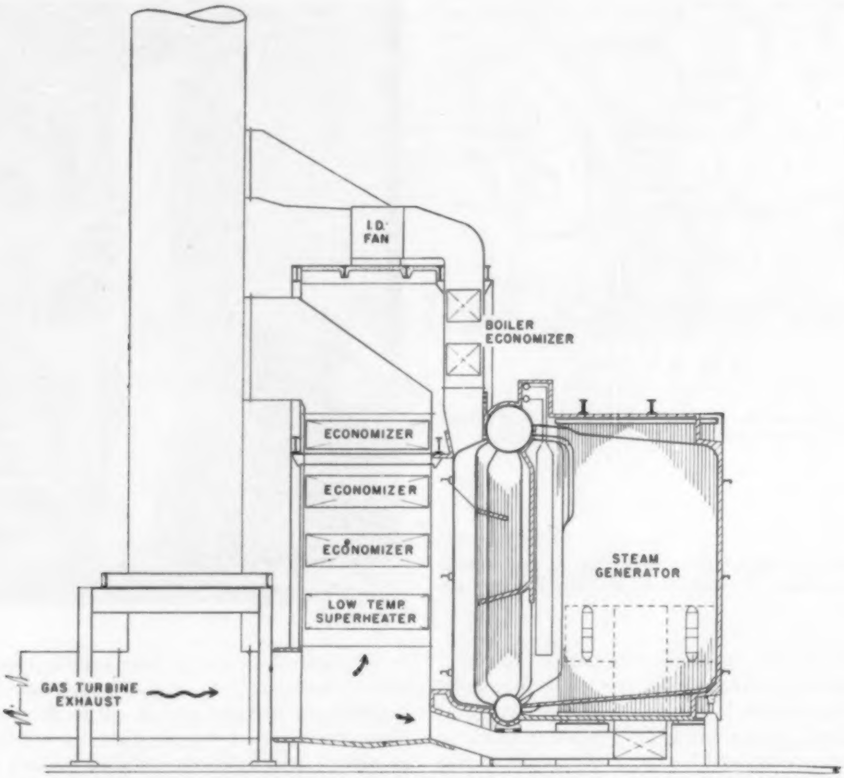


Fig. 6—Arrangement of exhaust-fed boiler and waste heat recovery equipment for a 16,500 kw gas turbine

Fired Heat Recovery

Gas turbine exhaust normally has about 80 per cent of the oxygen found in free atmospheric air. It is therefore a medium capable of concurrently supplying to the furnace of a steam generator both sensible heat and oxygen for the combustion of a fuel. The second principal classification, comprising fired heat recovery and steam generating equipment, takes advantage of this fact and permits convenient subdivision into three categories as determined by the following conditions: (1) Combinations in which the turbine exhaust gas contains a quantity of oxygen much greater than that necessary for the supplemental fuel needed to produce the desired evaporation; (2) Combinations in which just enough oxygen is contained in the turbine exhaust to satisfy the needs for steam generation; (3) Combinations in which the amount of oxygen available in the turbine exhaust gas is less than that which is required for a given evaporation.

For the first of these, the quantity of exhaust gas available is considerably in excess of that required to burn the necessary fuel. In other words, less steam is required than can be generated by making full use of the oxygen in the exhaust gas. A unit designed for this condition is shown in Fig. 6. It incorporates a tangentially fired boiler of the bottom-supported type operating in parallel with a large waste-heat recovery section. It has a maximum continuous evaporation of 210,000 lbs per hr at 900 F and 850 psig at the superheater outlet and is designed to handle over 900,000 lbs of turbine exhaust gas per hr. During combined operation a slight suction is maintained in the furnace and a backpressure of less than 4-in. w.g. is imposed upon the gas turbine. About one-quarter of the exhaust flow passes through the burners to support the combustion of the fuel fired.

Engineering studies and operating experience have shown that maintaining a constant weight flow of gas over a superheater through a wide range of loads can cause a rising total steam temperature with decrease in load. This characteristic, which is contrary to that exhibited by conventionally fired boilers, poses a serious problem of superheater metal selection, protection, and control. The difficulty has been resolved in the illustrated design by dividing the superheater into two parts and locating the initial or low-temperature stage in the by-pass section before the economizer. This scheme operates to control steam temperature down to half load by proportioning gas turbine exhaust flow over the two sections of the superheater.

It is often an important requirement for a steam generator designed for these conditions to be able to function on its own when the gas turbine is down. It therefore may be desirable to be able to obtain the same capacity and steam temperature when it is fired conventionally using atmospheric air. When operated in this way, increased gas and higher gas temperature are made available to the superheater than is the case when turbine exhaust is being utilized. Dangerously high steam temperature or excessive desuperheating would result if the entire superheater surface required for use with turbine exhaust were put in the boiler. Consequently, only sufficient superheater surface is installed in the boiler to obtain full

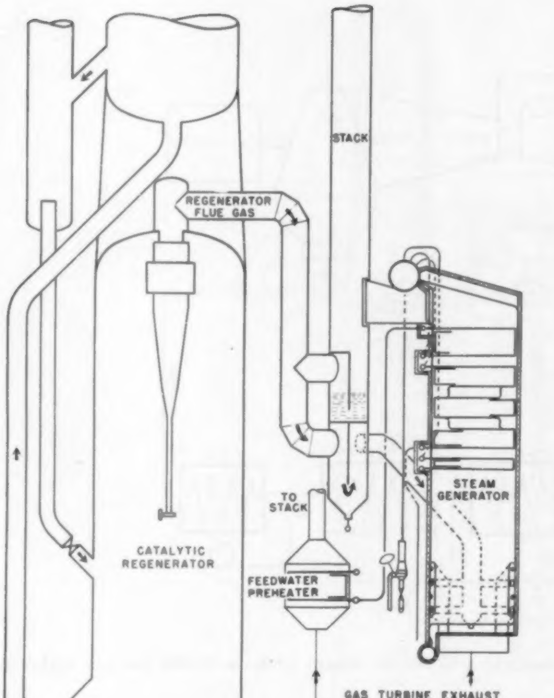


Fig. 7—Diagram of air and gas flows through a system using a catalytic cracking regenerator, gas turbine driven compressor and a CO boiler

steam temperature with cold air firing, and the additional surface required for combined operation only is placed in the stream of gas that bypasses the boiler.

It might be noted at this point, that, for a given power output from such a combination of gas and steam turbines, there are three possibi ities: (a) the steam output can be held constant and the gas turbine plant made to take the load sw.ngs; (b) the gas turbine output can be held constant and the steam turbine made to take the load swings; or (c) both gas and steam turbines may be arranged to follow the load swings in unison. One of these methods of accepting load will effect a greater economy than the others.

An extension to the application of this condition of high excess oxygen has recently been developed in the oil refining industry. It consists of a system in which the carbon monoxide-bearing gas from a petroleum cracking regenerator combines with the exhaust of a gas turbine to produce steam in what is commonly called a CO boiler. In the catalytic cracking of petroleum it is necessary to regenerate the catalyst continuously to maintain maximum cracker output. This involves the removal of coke deposited on the catalyst in the cracking operation and is accomplished in a vessel called a regenerator, through which the hot spent catalyst is circulated and scoured with air to burn off the coke. Relieved of these deposits, catalyst is returned to the cracker for further use. Fig. 7 illustrates how this process is tied in with a fired steam generator and gas turbine.

The gas turbine supplies mechanical power to drive an air compressor, which delivers air at about 30 psi to the regenerator where it burns off the coke from the circulating catalyst. The products of this reaction pass off as a 1050 F gas containing 6 per cent to 9 per cent carbon monoxide. The heating value of the gas averages about 40 Btu per cu ft of which half is attributable to the carbon monoxide content. Since this is insufficient combustible for stable burning, the gas is burned together with a supplementary fuel, usually refinery gas or oil. The exhaust gas leaving the turbine at approximately 850 F is conducted to the CO boiler, where half of it is used to supply the oxygen for both the regenerator ex t gas and the supplementary fuel The other half is reduced to stack temperature by a feedwater-preheating economizer. Fig. 8 shows a CO boiler design suitable for this cycle.

The next type of fuel-fired unit is that in which the turbine exhaust is sufficient to burn the fuel fired with reasonable excess oxygen. Thus, for the same gas flow, a much higher evaporation is possible than when only part of the turbine exhaust is used. Such a situation will produce the most efficient combination of gas turbine and exhaust-fed boiler. The heat balance diagram in Fig. 9 is representative of an exhaust heat recovery cycle combining a 60,000 kw steam turbine with a 10,000 kw simple-cycle single-shaft gas turbine. The arrangement incorporates a stack gas cooler that operates in the capacity of an intermediate feedwater heater in order to reduce the stack temperature to a level comparable to that of a straight steam cycle employing an air heater.

Fig. 10 illustrates the organization of an 1800 psig/1000 F/1000 F reheat boiler, economizer, and stack gas cooler set up for this type of application. At peak boiler load, the full flow of turbine exhaust gas enters the furnace tangentially along with the fuel. The products of combustion then pass over the superheater, reheater, economizers, and stack cooler, and are exhausted to atmosphere. The control of steam temperature is accomplished through bypass of turbine exhaust around the furnace. The size of this boiler is the same as one

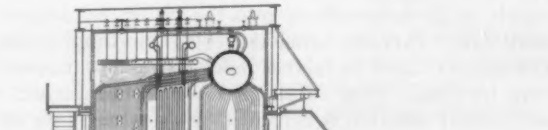


Fig. 8—Combustion Engineering type VU-40 CO boiler of a size to deliver 200,000 lb per hr of steam at 650 psig, 750 F

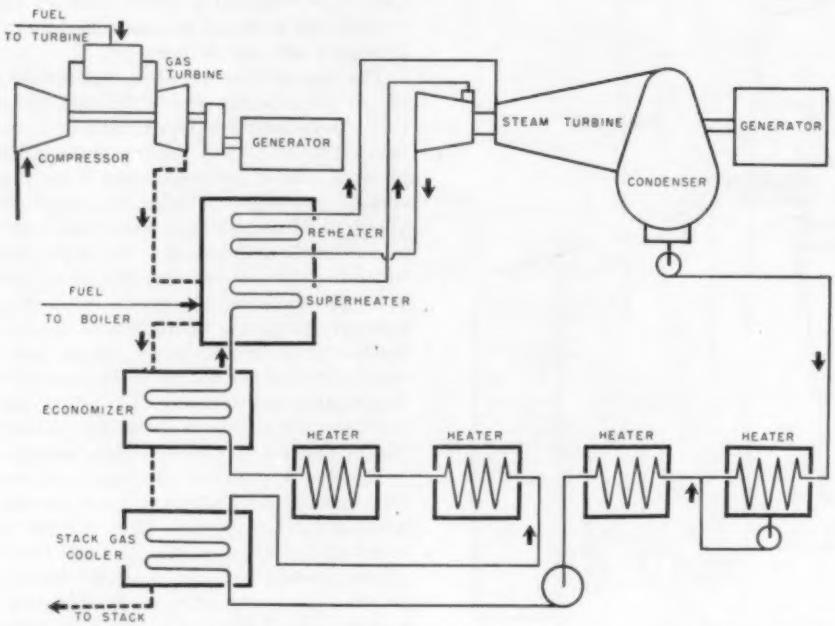


Fig. 9—Heat balance diagram for steam-gas power plant combining 60,000 kw steam turbine, 10,000 kw gas turbine

that would be selected for a conventional cycle with the same steam conditions. Its cost is increased somewhat by the stack cooler, but this additional expense must be balanced off against the saving entailed in omitting a feedwater heater from the condensate return line and in omitting an air heater.

The last condition for the fired type boiler used in conjunction with a gas turbine is one in which the exhaust contains insufficient oxygen to burn the fuel for the specified evaporation. Typical of this arrangement would be the operation of a 5000 kw gas turbine to supplement the power output of a 60,000 kw steam turbine, or a 10,000 kw gas turbine to supplement a 120,000 kw steam steam turbine. The full exhaust of the turbine is passed through the boiler furnace, and an additional supply of air is introduced into the system by a forced draft fan. This air, being the coldest medium in the system, is utilized to further reduce the stack temperature by employment of an air heater. Here again, a satisfactory solution is dependent very strongly on the percentage breakdown between the kilowatts produced by the gas and steam turbine generators, as well as on the efficiency of the steam cycle itself. In this case, these things affect the ratio of the air-to-gas weights passing through the air heater. This ratio is the indicator of the effectiveness of the air heater in reducing stack temperature. A careful evaluation should be made if the supplemental air weight is less than one-quarter of the gas weight, because the cost of the air heater will be difficult to justify. For maximum economy of operation, the forced draft fan and air heater must be kept in operation at all times. Therefore, the use of this scheme seems to be limited to combinations in which the steam generating unit is base-loaded and load swings are taken by the gas turbine.

Supercharged Boilers

In the supercharged cycle the furnace of the steam generator, operating at compressor discharge pressure of from 50 to 75 psig, acts also as the combustion chamber of the gas turbine. In this type of unit the compressor operates as a forced draft fan supplying combustion air to the furnace. The products of combustion are discharged from the boiler to the gas turbine and thus perform useful work. Fig. 11 schematically illustrates the supercharged cycle.

Although gas turbines with internal combustors have to operate at 400 to 600 per cent excess air, supercharged boilers with water-cooled furnaces can operate with excess air values as low as 10 per cent. The gas turbine compressor is sized in accordance with the air requirements of the steam generator as would be a forced draft fan. Combustion of all the fuel, both that required for the generation of steam and the operation of the gas turbine, takes place in the furnace of the steam generating unit. Steam can be produced at any pressure or temperature and for any type of steam cycle. The high temperature pressurized gas leaves the boiler and passes to the gas turbine where it produces only sufficient power to drive the compressor under one method of operation, or to drive the compressor and generate additional power under an extension of this method.

Under the first consideration, where no additional power is produced by the gas turbine, the justification for the use of this cycle, as against the use of a conventional boiler operating with a forced draft fan, is in the reduction of the size of steam generating equipment made possible by the increased gas radiation rate in the furnace and higher heat transfer rates in the convection banks. These increased rates result from the high pressure level and higher pressure drops that are made available in such a system.

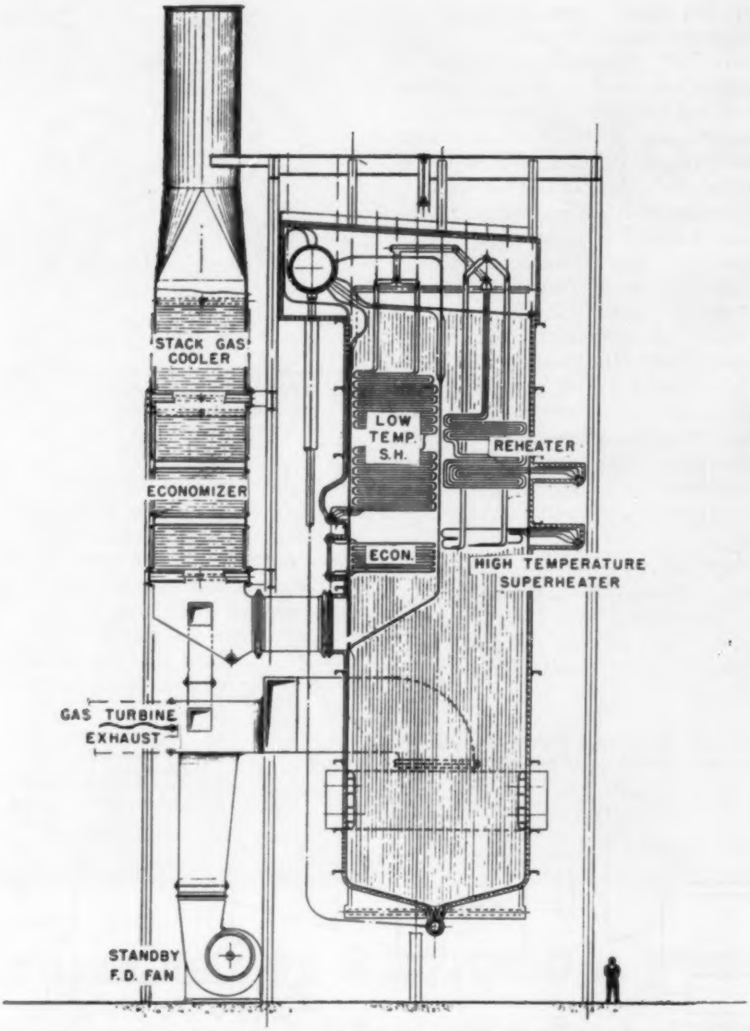


Fig. 10—An 1800 psig, 1000 F, 1000 F reheat boiler, economizer and stack cooler has been set up for full flow of exhaust gas at peak boiler load. Steam temperature is controlled by bypassing turbine exhaust around the furnace

Under the second consideration, by raising the temperature of the combustion products to the turbine by 400 degrees F to 600 degrees F, excess power is generated. With a supercharged cycle in which such additional power is produced by the gas turbine, the advantage to be gained is a compact steam generating unit with a bonus of low cost gas turbine-generated power.

Although the prospect of a smaller steam generator makes this scheme attractive, there are items that detract from the possible economic advantages. One of these is that a reduction of surface does not, in all cases, mean a proportionate reduction of cost. For less surface to do the same job, it is necessary for it to operate at higher metal temperatures and, consequently, to be made of better materials. Further, the engineering and fabrication considerations required to make this arrangement into a working affair are extensive and costly. It appears that this will be so for some time, and the first few installations for utility or large industrial use will probably be made by organizations that have venture capital to spare and will not consider them sources of firm power. The fact that the steam generating equipment occupies less space indicates a reduction in capital outlay for building and property. However, this advantage is somewhat offset by the space provided for the gas turbine.

To date, domestic investigations into this type of cycle have been restricted to those in which clean-burning fuels are used. Considerable work is still required before this scheme can be adapted for coal or commercial grades of fuel oil.

Closed Cycle Gas Heaters

The last consideration is the closed cycle. Fig. 12 points out the difference between the simple open cycle and the basic closed cycle. In the open cycle, atmospheric air is compressed, raised in temperature in the combustion chamber, and passed to the turbine, which exhausts it to a stack. In the closed cycle, however, the turbine exhaust gas is passed through a precooler and then readmitted to the compressor. The gas leaves the

compressor under pressure and is passed on to a gas heater, which may be of the separately fired or integral convection type. Here, its temperature is raised to about 1200 F. It is then admitted to the gas turbine, from which it is again recycled through the precooler.

The advantages that this cycle seems to offer are, first, that air, nitrogen, or other gases can be used, and, because mixing with the products of combustion does not occur, clean gas is delivered to the turbine; and, secondly, since the circuit is closed and the working medium is isolated, any type of heat exchange device, fired with any fuel, can be used without introducing any complications that are not had with existing types of steam generating equipment for the same temperatures and pressures.

Possibly the best application of the closed cycle system lies in its use with a conventional regenerative steam cycle. Here, the gas heater may be handled in the same manner as a superheater or a reheater convection bank to produce a balanced power output with the steam cycle. Such an arrangement appears to offer good possibilities for effective use in combined gas-steam cycles.

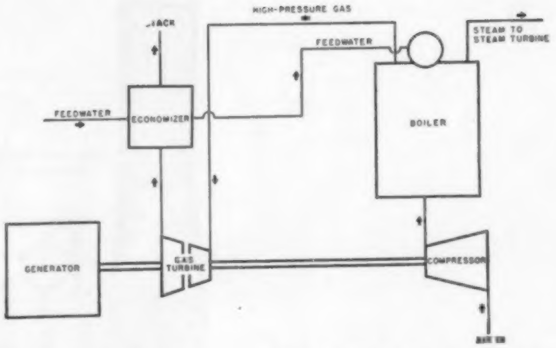
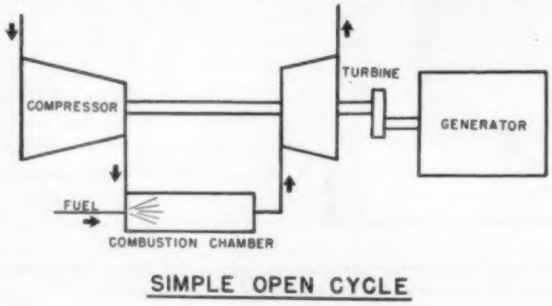


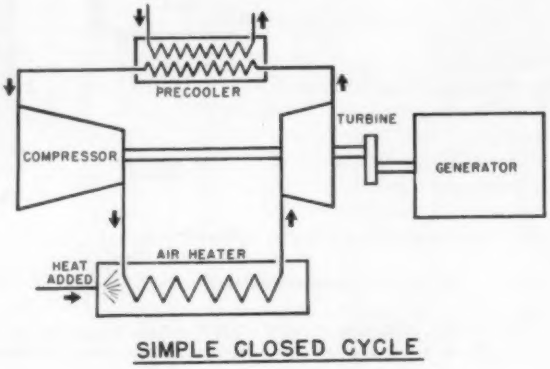
Fig. 11—Supercharged cycle makes use of gas turbine in the manner shown above. Here the boiler discharges gaseous products of combustion direct to the gas turbine

Conclusions

The thermodynamic and operating characteristics of a combined steam-gas power plant are a composite of those of the steam turbine, gas turbine, and steam generator. The complexity that can result calls for close cooperation between turbine and boiler designers to enable them to present a valid picture of the economics involved. The classifications of combined plants suggested in this paper will be of assistance in (1) determining the particular category into which desired boiler or heat recovery equipment will fall, (2) defining exactly what is required of steam generating equipment to be used with gas turbines, and (3) indicating the direction in which to concentrate engineering effort.

Fig. 12—Differences between the simple open cycle gas turbine as against the basic closed cycle are shown here





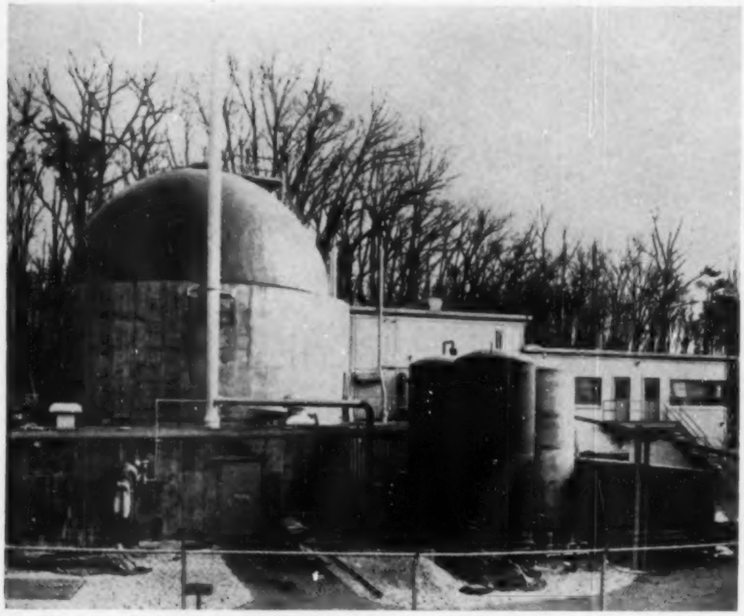
APCA Plans June Meeting

The Golden Jubilee meeting of the Air Pollution Control Assn. co-sponsored by the Pollution Control committees of the ASME, the American Meteorological Society, the American Institute of Chemical Engineers and the American Society of Heating and Air Conditioning Engineers, is scheduled for the Hotel Sheraton-Jefferson, St. Louis, Mo., June 2–6, 1957. Eleven technical sessions will be held over a three-day period, Monday, June 3, through Wednesday, June 5. Thursday, June 6, has been reserved for a control official's conference.

This is the first year that the APCA Meeting has been co-sponsored. The individual societies are scheduling a number of sessions with speakers and subject matter of interest to their specific membership. Two papers of particular interest to power field people will be given on flue gas scrubbing. The one is a description of the Fulham-Simon-Carves process and the second is based on cost estimates of scrubbing to remove sulfur dioxide. A review and appraisal of air pollution legislation is also scheduled. One of the AIChE papers will cover the disposal of gaseous effluents from nuclear power plants.

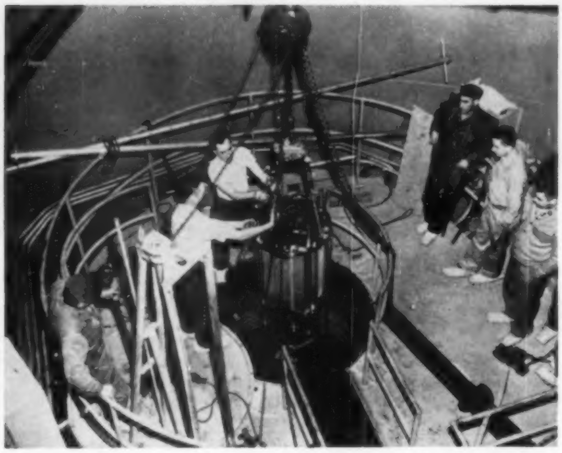
The social side of the meeting will feature addresses by Benjamin Linsky, president of the APCA, and by R. A. Tucker, mayor of St. Louis. Mr. Tucker was very prominently identified with the early work of establishing the St. Louis ordinance for air pollution control.

The Army

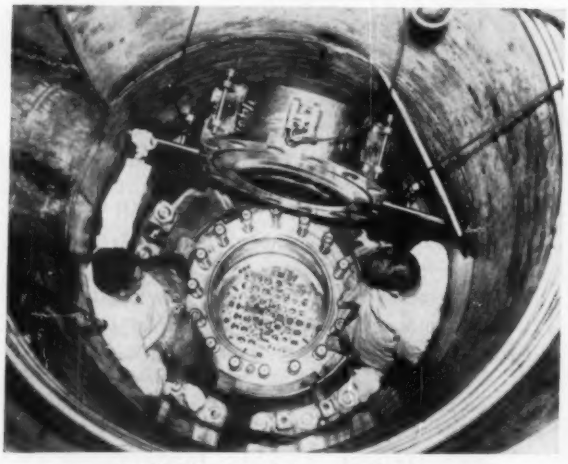


General view looking north; vapor container at left

Loading dummy fuel elements



Technicians setting the core structure

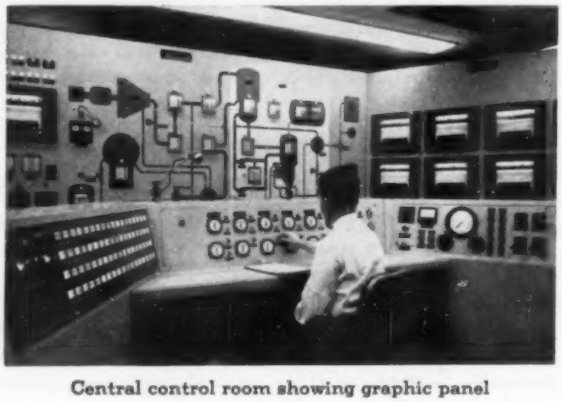


Overhead view of the core structure

THE Army Package Power Reactor at Fort Belvoir, Virginia, which was first test operated on April 8, 1957, was dedicated on April 29. Wilber M. Brucker, Secretary of the Army, and Lewis L. Strauss, Chairman of the Atomic Energy Commission, participated in the ceremonies during which the power output of the plant was utilized to operate a radar antenna and a printing press.

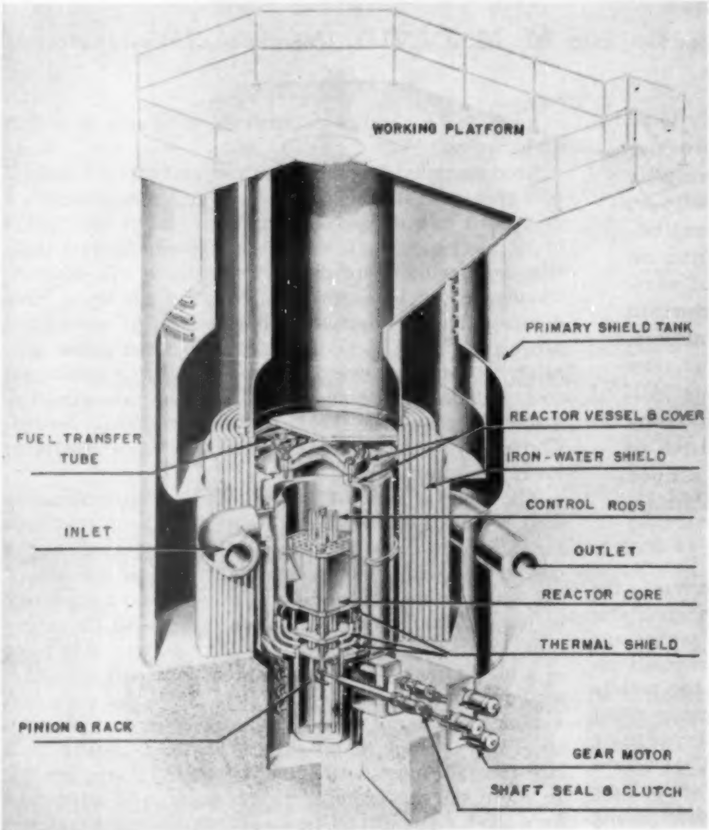
Alco Products, Inc., contracted with the AEC to build this reactor on the first fixed-price contract let in this country for an atomic reactor. The contract, originally for $2,096,753, was awarded on December 10, 1954, and ground was broken on October 5, 1955. Stone & Webster Engineering Corp. served as engineer-constructor for the project. Estimated overall construction cost, including architectural engineering, fuel element fabrication, testing and training operation, is $3,500,000.

The pressurized-water reactor is of the heterogeneous type employing light water moderator and fully enriched uranium. It has a heat output of 10,000 kw and a net electrical output of 1975 kw at 1.5 in. Hg. Rated steam flow is 34,070 lb per hr at 200 psia. Average reactor heat flux is 55,900 Btu per hr per sq ft.

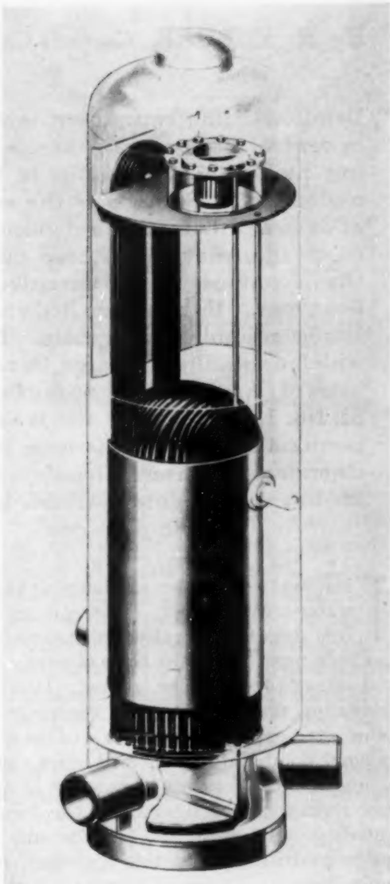


Central control room showing graphic panel

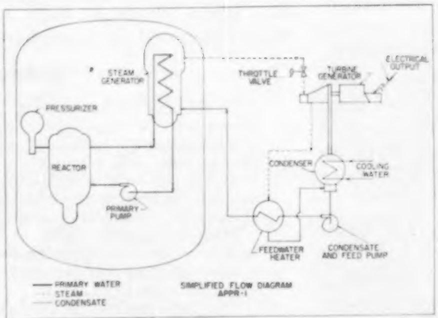
Package Power Reactor



Isometric drawing of the reactor vessel, core and control rod structure



Steam generator having a total effective heating surface of 1030 sq ft including superheater



Cutaway view of Alco-designed control-rod drive mechanism

Completed stationary fuel assembly

Costs of Cation Exchange Equipment

By R. F. PEAK, Cascade Cartridge Co. and M. M. DAVID, University of Washington

Demineralizing equipment is widely used in central stations, and its rôle in producing high-quality makeup is thoroughly understood. Because of the competition of different methods for demineralization, much information has been published on the advantages and disadvantages of various types. By contrast, little information has been published on costs. This article, which originally appeared in the January issue of *Chemical Engineering Progress* (Vol. 53, No. 1, pp. 37J–40J) and is reprinted by permission of the American Institute of Chemical Engineers, therefore fills a need for having cost data available for estimating purposes.

THE major use of ion exchange in the past was in the water-treating field. Hence, much of the available cost data for ion exchange materials and equipment has been reported on the basis of amounts, compositions, and rates of water to be treated. However, the rapidly increasing utilization of ion exchange in many other fields often requires examination of the feasibility of using various combinations of bed sizes, shapes, and flow arrangements; for this purpose it is desirable to have cost data available in more basic form and in larger quantity. Monet (3) and Mindler and Paulson (2) have made contributions in this direction, but considerably more data are necessary to permit satisfactory working estimates of ion exchange equipment costs. Accordingly, information of this type for cation exchange equipment has been compiled from the literature and obtained from ion exchange equipment manufacturers, and is presented in the following sections. In addition some data on anion exchange equipment and other costs have been computed and are also presented.

Companies furnishing data for the study are listed hereinafter. Each company contributed at least ten datum points, with the majority of companies furnishing many more than the minimum. In part, price information furnished by the companies represented working estimates, rather than exact costs. All the cost data have been corrected to an "Engineering News Record" Construction Index of 650 (Marshall Stevens Index of 190).

Sodium Cycle Operation

The f.o.b. costs of mild steel ion exchange units with sodium chloride regenerant are shown in Figs. 1 and 2 as a function of bed volume. Each of the curves shown is based on more than 250 datum points. The data spread is only ±15 per cent, even though variables of pipe diameter, bed diameter, and tank shell thickness were ignored. Solo-valve and multivalve units were indistinguishable in cost, and all units have been plotted on the same curves. The cost ratio of duplex- to single-bed units is 2:1 for either polystyrene or synthetic zeolite exchange materials.

Recommended flow rates for these units are generally 2 to 3 gpm/cu ft for the smaller beds and approximately 8 gpm/sq ft of bed cross-sectional area for the bed depths of 36 in. or more. However, some manufacturers state that flow rates up to nearly twice these will not materially reduce bed capacity. Most of the units have depth-to-diameter ratios falling within a prescribed range (see Fig. 11). For depth-to-diameter ratios definitely below the range of common usage, an additional cost of 10 per cent should be added to the values in Figs. 1 and 2 because of the larger diameter tank needed. Conversely, a large depth-to-diameter ratio results in lower equipment cost.

The slopes of the cost lines in Fig. 1 are approximately 0.86, which is higher than the usual scale-up exponent for equipment costs. This high value is due partly to the cost of the resin, which is essentially a linear function of the bed volume. In addition the increased complexity of the collection and distribution systems of the larger units tends to raise their costs. The difference in price of a high capacity polystyrene resin unit (Fig. 1) and a medium capacity zeolite unit (Fig. 2) of the same bed volume reflects not only the difference in cost between the two exchange materials but also the smaller tank size generally used with the latter material (see below). In addition a smaller regenerant makeup tank is required for a given volume of medium capacity exchange material than for the same bed volume of high capacity resin. The prices shown in Figs. 1 and 2 are relatively close when compared on an exchange capacity basis.

Notation

To simplify understanding, the following definitions are presented:

High-capacity resin. A sulfonated cross-linked polystyrene resin with a capacity of approximately 30 kilograins ($CaCO_3$) per cu ft when regenerated with 15 lb of salt per cu ft. Examples are Amberlite IR-120, Nalcite HCR (Dowex 50), Permutit Q, and Chempro C-20.

Medium-capacity resin. A sulfonated polystyrene resin with a capacity of approximately 20 kilograins per cu ft at a salt dosage of 5 lb per cu ft. Examples are Duolite C-25 and Amberlite IR-112.

Synthetic zeolite. A synthetic, inorganic gel material of the sodium aluminosilicate family, with a capacity of approximately 15 kilograins per cu ft at a salt dosage of 6 lb per cu ft. Examples are Nalcolite and Crystalite.

Solo-valve unit. An ion exchange unit with a multiple-port valve so arranged that flow of treated solution, backwash water, regenerant solution, and rinse water are all controlled by the single valve.

Multiple-valve unit. An ion exchange unit whose operation is controlled by valves located in the several pipe lines supplying the unit. The flows of feed, regenerant solution, rinse, and backwash require the operation in the proper sequence of more than one valve.

Single-bed unit. An ion exchange system consisting of one bed of exchange material, one regenerant make-up tank, and the necessary piping and valves.

Duplex-bed unit. An ion exchange system containing two beds of exchange material, one regenerant make-up tank, and the necessary piping and valves to permit operation of either bed while the other is being regenerated.

Bed volume. The volume occupied by the exchange material only.

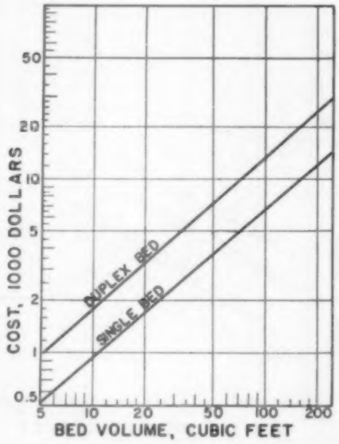


Fig. 1.—Costs (f.o.b.) of mild steel cation exchange units, high capacity resin

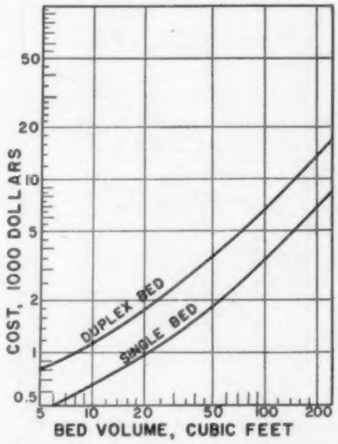


Fig. 2—Costs (f.o.b.) of mild steel cation exchange units, medium capacity synthetic zeolite

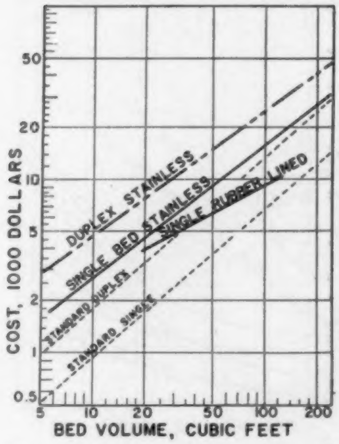


Fig. 3—Costs (f.o.b.) of acid cycle cation exchange units with high capacity resin

Acid Cycle Operation

Cation exchange systems employing an acid regenerant generally use rubber-lined or stainless steel equipment, and the f.o.b. costs of such units as shown in Fig. 3 are higher than those for sodium cycle units. All original cost data obtained for these types of system were for single-bed units, and the prices of the duplex units were computed from these original data. The curves for single-bed units are each based on less than twenty-five datum points. For comparative purposes the costs of standard sodium cycle mild steel units with high capacity resin are included in Fig. 3.

The cost of duplex stainless steel units was computed by two methods: (1) by use of the duplex-to-single bed ratio for standard mild steel units; and (2) by the addition of the costs of an extra tank, necessary valves, and resin to the cost of a single unit. The ratio method resulted in cost figures 3 per cent higher for small units and 20 per cent higher for large units. The curve shown is a compromise between the two sets of values.

The slope of the curve for single-bed stainless units is 0.78, which is closer to the common 0.6 scale-up factor and reflects the increased cost of the tank and pipes. As a rule of thumb, acid-cycle unit costs are often estimated at 1.75 to twice those of standard sodium-cycle units. Data of Fig. 3 suggest this is satisfactory for rubber-lined units, but indicate that the factor should be 2.5 to 3 for stainless steel equipment.

Installation

Three types of installation costs for cation exchange units are shown in Fig. 4. The lowest pair of curves represents the expense of hooking up a unit after it has been erected on a prepared foundation. The middle pair of lines presents the cost of erection plus piping hookup. The top pair of lines represent total installation costs, that is, all costs except freight, which must be added to the f.o.b. price to provide the total installed price. The lower pairs of lines are from values provided by equipment manufacturers and are based on approximately sixty datum points. The highest pair of lines was computed by the method of Lang (1), and the values thereon include cost of a foundation (as 5 per cent of purchase cost plus freight) and transportation of equipment from railyard to job site, erection, and hookup (as an additional 17 per cent of purchase cost plus freight). Lang's factor of 8 per cent for supports and platforms has been considered as included in the purchase price of the units, since ion exchange units are commonly sold and shipped completely fabricated, with all necessary parts included The cost of freight needed for Lang's method was taken as $27.50/1000 lb and was based on an 800-mile shipment.

Installation costs of Fig. 4 can be added to the purchase prices of Figs. 1, 2, and 3, to obtain installed costs exclusive of freight.

Automatic Controls

Automatic controls on a cation-exchange unit are definitely an additional expense and are so quoted by manufacturing companies. Approximate prices for automatic controls for a single-bed unit are shown in Fig. 5. These costs are for manually or time-clock initiated programming of the regeneration cycle. Completely automatic regulation of the exchange cycle, controlled by gallonage or effluent quality, will be more expensive because of the additional instruments and controls required. To a considerable extent, the cost of automatic controls is dependent on the pipe size used with a unit. Accordingly, dashed lines have been included in Fig. 5 to indicate the pipe size commonly used with various bed sizes and the cost of control equipment for that pipe size.

Use of automatic controls on a duplex unit usually will require a duplication of the controls and valves for a single unit and also cross-over valves and interlocks. Hence, automatic controls for a duplex unit will probably cost from $2^1/_2$ to 3 times as much as for a single-bed unit.

Small Units

A limited amount of cost data was collected for small deionizing units which perform both cation and anion exchange. These data are presented in Fig. 6. The upper two curves are for units in which separate beds are used for cation and anion exchange; the lower curve is for

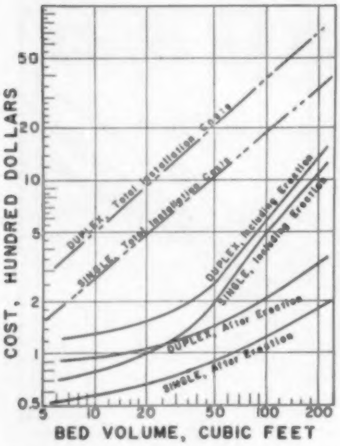


Fig. 4—Installation costs for cation exchange units

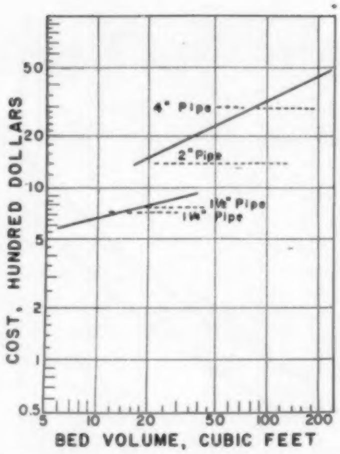


Fig. 5—Costs of automatic controls for single bed cation exchange units

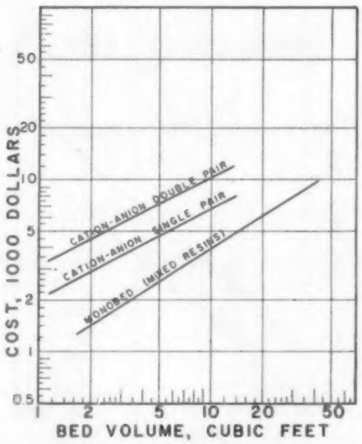


Fig. 6—Prices (f.o.b.) for small bed ion exchange units

monobed units. It should be noted that the bed size for the monobed units is the total bed size (with the cation exchange material occupying approximately half the total volume), but the bed size shown for the multiple-bed units is the size of each single bed. Generally the cation and anion exchange beds were nearly the same in size. All the small units were equipped with either a purity meter or automatic controls, the cost of which is included in the prices shown.

The installation cost for a small unit should approximately equal the cost of hooking up a single-bed standard unit, if the special unit is shipped completely assembled and mounted on skids. If the unit is not factory assembled, the installation cost would be that for the same number of standard beds of the same size.

Ion Exchange Resin

The information collected on the costs of ion exchange materials is summarized in Table 1. The sale of ion exchange resins is an extremely competitive process in which the actual manufacturer usually markets his products through equipment and engineering firms. This is similar to the customary wholesaler-retailer-consumer system of distribution. Hence, even more variation in cost can be encountered than is indicated in Table 1. The prices quoted by the exchange material manufacturers for direct sale of small quantities are sometimes slightly higher than those quoted by the equipment sales companies for replacement resin.

TABLE 1—RESIN PRICES AS QUOTED*

Resin	Price: Small lots, 1–9 cu ft	Price: L.C.L. lots, 10–200 cu ft
High capacity polystyrene resins: Chempro C 20, Amberlite IR-120, Dowex 50, Nalcite HCR, etc.	\$30.00 32.00	\$21.00 26.00
Medium capacity resins and synthetic zeolites: Duolite C-25, Illco C 21, Eltorex, etc.	23.00 25.00	19.00 22.00
Strongly basic resins:† Amberlite IRA-410 and IRA-400; Nalcite WBR; Duolite A-2, A-7, A-114; etc.	74.00 88.00	65.00 75.00
Weakly basic resins:† Amberlite IRA-4B, IRA 45; Nalcite WBR; Duolite A-2, A-7, A-114; etc.	47.00 68.00	38.00 60.00

* Prices for greensands and sulfonated coals were not solicited because of their decreasing usage, especially in cycles inolving fluids other than water.

† Data for prices of anion exchange resins were collected for calculations and estimates of the cost of anion exchange units. The material is incomplete and is presented as a guide only.

Derived Cost Data

Data solicited from manufacturers in the present study were limited to cation exchange equipment. Because of the expanding interest in special ion exchange cycles, the preceding data have been used to compute costs of anion exchange equipment and of the equipment without resin. Computed costs for anion exchange equipment agree sufficiently well with published values (2, 3) to provide confidence in their use for preliminary cost estimates. However, the data presented in this section are intended only to serve as a preliminary guide.

Anion exchange equipment cost data are presented in Fig. 7. These were obtained by adding the difference in cost between anion exchange material and cation exchange material to the cost of the corresponding cation exchange unit. The cost of the anion exchange resin was taken as \$71.50/cu ft and of the cation exchange resin as \$21.50/cu ft. These prices are somewhat higher than the cost of the resins to the equipment manufacturer.

The costs of "empty" ion exchange units shown in Figs. 8 and 9 were computed by two methods: (1) subtracting the cost of the resin from the cost of the unit given in Figs. 1 through 3; and (2) adding costs of the valves, tanks, and regenerant makeup tank. In the second method it was not feasible to assign costs to the regenerant and feed distribution and collection systems, and accordingly the curves in Figs. 8 and 9 have been drawn to favor the values computed by the first method as indicated.

Bed Weights, Depth Per Diameter Ratios

Information on shipping weights of cation exchange units is necessary for computing shipping charges and preparing foundations. This information is presented in Fig. 10 for sodium-cycle units. The weight of an ion exchange unit varies considerably less for a given size unit than does the cost. The curves shown are for both resin and synthetic zeolite units, as all the data grouped well into the two lines given. Equipment filled with synthetic zeolite tends to have a slightly smaller shipping weight than resin-filled equipment. Synthetic zeolites are generally used in deeper beds and the units have a smaller free volume for backwashing. Hence, the tank size

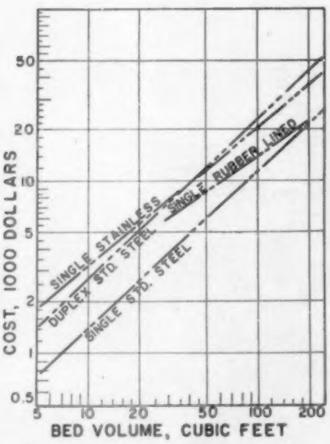


Fig. 7—Estimated costs (f.o.b.) for anion strongly basic resin exchange units

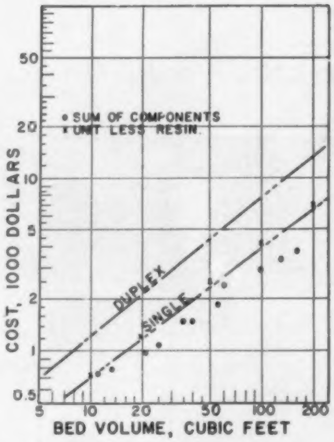


Fig. 8—Estimated costs for "empty" mild steel ion exchange units

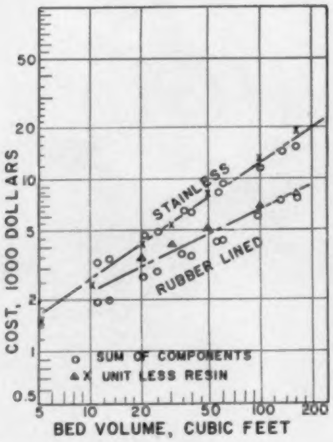


Fig. 9—Estimated costs (f.o.b.) for "empty" acid cycle ion exchange units

needed for a given volume of exchange material usually is smaller.

Specifications of the manufacturers were used to find the depth-to-diameter ratios of standard cation exchange units, as plotted in Fig. 11. As referred to previously, values lying below the major grouping of points represent larger tank diameters with concomitant higher equipment costs. Standard tanks are customarily used for ion exchange equipment, and such tanks are usually available from stock in 6-in. increments of diameter. The designer of special cycles can select his bed diameter accordingly and take advantage of the lessened cost.

Engineering

In the design of ion exchange equipment for special purposes, interpretation of rate and of equilibrium data requires judgment and experience. Most manufacturers of ion exchange equipment prefer to protect the reputation of their equipment by assisting the customer in preparing the design. The normal amount of custom design engineering represents an additional charge of 10 to 12 per cent of the purchase cost. Special laboratory work to establish suitable resins and optimum operating conditions will add still further expense.

Acknowledgment

The authors wish to express their appreciation for the data and comments contributed by the following companies:

AquaMatic, Inc., Rockford, Ill.
Barnstead Still and Sterilizer Co., Boston, Mass.
Chemical Process Co., Redwood City, Calif.
Culligan, Inc., Northbrook, Ill.
Dorr-Oliver, Inc., Stamford, Conn.
Elgin Softener Corp., Elgin, Ill.
Hungerford and Terry, Inc., Clayton, N. J.
Illinois Water Treatment Co., Rockford, Ill.
Infilco, Inc., Tucson, Ariz.
Los Angeles Water Softener Co., Inc., Los Angeles, Calif.
National Aluminate Corp., Chicago, Ill.
Oshkosh Filter and Softener Co., Oshkosh, Wis.
Rohm and Haas Co., Philadelphia, Pa.
Herbert Wolcott, Columbia, Mo.

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2. Mindler, A., and C. E. Paulson, *Chem. Week*, **75,** No. 5, 45 (December 18, 1954).
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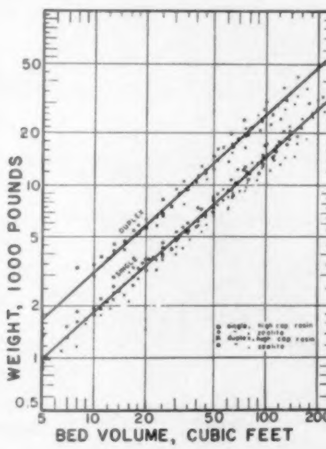


Fig. 10—Shipping weights of mild steel cation exchange units (complete with resin and bed support gravel)

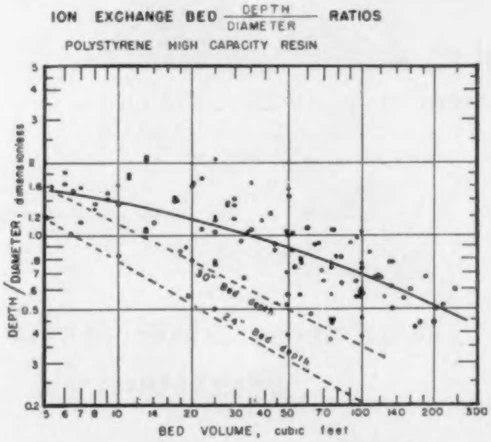
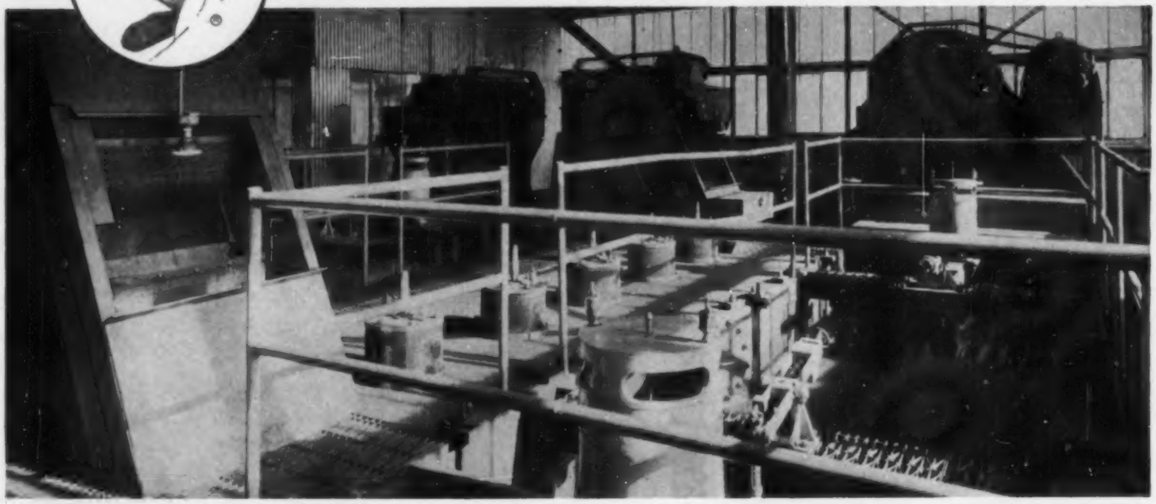


Fig. 11—Ion exchange bed depth per diameter ratios

WHY CHESSIE'S RAILWAY IS FIRST IN COAL



SUPERIOR COAL. The entire output of this mine is processed by automatic compound coal cleaning equipment. Producers on the Chesapeake and Ohio are prepared to supply you with highest quality coal of the type best suited to your needs and processed to your own specifications.

SUPERIOR SERVICE. To its present fleet of 63,780 coal cars—largest in the world—C & O is adding another 8,000. New high-speed yards, new locomotives and a new teletype car reporting system bring you faster, more dependable service.

For dependable deliveries of top quality coals, contact coal producers on the C & O. And for specific help in meeting your own fuel requirements, write to: R. C. Riedinger, General Coal Traffic Manager, Chesapeake and Ohio Railway Co., Terminal Tower, Cleveland 1, Ohio.

Chesapeake and Ohio Railway

WORLD'S LARGEST CARRIER OF BITUMINOUS COAL

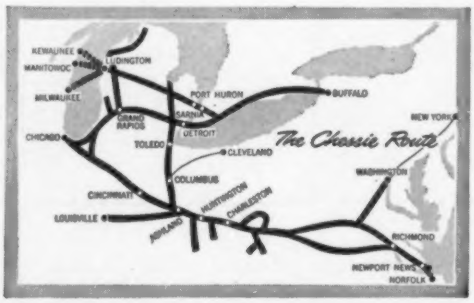


Fig. 1—Power plant wastes are gradually coming under control and within ten years will be valuable materials. Above photo shows a demonstration at the Agglomeration Laboratory of Koppers Co. wherein boiler flyash is being transformed into a usable lightweight aggregate for concrete

*A Power Engineer Looks Ahead Ten Years**

This article is based on a paper before the Conference of Metropolitan Student Chapters of the American Society of Civil Engineers, Nov. 3, 1956. It describes the growth potential of the power industry so effectively to all student engineers, civil or otherwise, that we offer it to our readers as a possible aid in recruitment

By THEODORE BAUMEISTER

Stevens Professor of Mechanical Engineering, Columbia University; and Consulting Power Engineer, New York N. Y.

IN discussing what appears to lie ahead in the next ten years—for the civil engineer in the field of power—it is necessary first to take a brief look backward. Since 1900 the electric power industry has reduced fuel consumption from 7 lb of coal per kilowatt-hour to less than one pound. See Table I. In the face of rising coal prices, this means that today the cost of coal for producing electric energy, in mills per kwhr, is no more than it was in 1900. See Table II. Put another way, if there had not been this improvement in thermal efficiency, and we were compelled today to accept the thermal performance of 1900, the entire coal producing capacity of all the nation's coal mines would be insufficient to meet the demands of the electric industry alone. There would not be enough coal for the power industry, let alone for any other uses.

This is only one item that can be cited in the march of progress, and there is no good reason to suppose that the march will be stopped in the next ten years. It cannot be as spectacular in the improvement of fuel economy but there are plenty of other areas in which progress can be made. Some people advise young engineers to shun the power field. Their advice is predicated on the belief that no more progress can be expected—just a repetition of the same old story. Those who wish to accept that view can do so. There are others who visualize many changes, and most of those changes will have an impact on the civil engineering branch of the profession. Let us look at some of the probable influences.

*Reprinted by permission from *Civil Engineering*, December, 1956, pp 62–66 incl.

TABLE I.—OVERALL THERMAL PERFORMANCE OF U. S. ELECTRIC UTILITY POWER PLANTS

Year	Overall Plant Heat Rate, Btu per Kwhr (Approx.)
1900	90,000
1910	60,000
1920	36,000
1930	20,000
1940	16,400
1950	14,000
1954	12,200

TABLE II.—FUEL COST FOR GENERATION OF ELECTRICITY IN U. S. ELECTRIC UTILITY POWER PLANTS

Year	Dollars per ton of coal equivalent	Mills per KWHR
1917	3.52	4.7
1922	5.31	6.2
1932	3.30	2.3
1942	3.80	2.5
1947	5.60	3.7
1952	6.21	3.4
1954	6.25	3.1

TABLE III.—ESTIMATED ANNUAL ELECTRIC UTILITY GENERATION OF U. S.

Projected from 1950 figure of 329 billion kwhr

Year	—Billions of Kwhr Based on— Annual Growth of 4%	6%	8%
1955*	400	440	480
1960	490	590	700
1966	610	820	1,100
1970	720	1,050	1,500

* For the year 1955, the actual production was 546 billion kwhr.

The Fuel Picture

Every rational estimate of the growth of the electric power industry indicates a doubling of the installed capacity in the next ten years, as shown in Table III. This would mean the burning of some 250,000,000 tons of coal a year, approximately half the entire bituminous coal output of the nation today (Table IV). This coal will be transported in many different ways—by rail, barge, and truck. If we assume no improvement in the methods of carrying coal, it seems as incongruous to supply coal by car or truck to a single boiler unit burning 3 or 4 tons a minute, as to use wheelbarrows instead of carryalls for moving earth, or wooden barrels instead of tank cars for transporting oil. Belt conveyor systems for crushed coal, or pipelines, should be competitive with existing methods of moving coal—even with the electric transmission line in some areas. In considering the development of alternative methods of transporting coal it should be recognized that the present cost for transportation alone frequently exceeds the cost of the coal at the mine. This high cost of transportation is a tremendous incentive to the development of new devices or systems for moving coal more cheaply.

It is not logical to expect that, in the thermal powerhouses of the future, the size of coal bunkers will be greatly increased. Today's construction costs for bunkers, with heights of 100 ft and loads in thousands of tons, offer limitations that call for a new approach to the problem. It is reasonable to expect an extension of the current trend toward the outdoor type of power plant. Even metal and asbestos-type siding will be eliminated as was the tapestry brick and limestone trim of the old-style plants. This will introduce new structural, operational, and maintenance problems to meet the interrelated vagaries of climate, cost, and plant reliability. The figures cited on coal consumption in Table IV will stir the engineer's imagination and inspire him to seek out alternative sources of raw energy. Petroleum and natural gas should find decreasing use for stationary power applications because of cost and the increasing demands of mobile power plants. Hydro power also will become of less significance in the nation's power picture. See Table V. Some favored regions, like the Pacific Northwest, will continue their hydro development. The entire hydro potential of the country is estimated to be of the order of 100 million kw, and 500×10^9 kwhr in an average water year—if every potential site were harnessed. This complete harnessing is admittedly impossible; there are too many other needs for water.

Perhaps the most significant piece of evidence that can be found on the dwindling relative importance of hydro power is the fact that the TVA is already the country's largest coal buyer, and its purchases account for more than one tenth of all the coal used by the entire electric industry in the United States. Or again, from the viewpoint of the world as a whole, it should be remembered that "The burning of dung is a larger contributor to the world's energy than water power, in fact, ten times as large" (G. G. Brown, "Thinking Ahead: Nuclear and Solar Energy," *Harvard Business Review*, Vol. 34, No. 17, 1956).

Large Nuclear Fuel Reserves

There are other sources of raw energy like the tides, the wind, the waves, and the sun, but these offer little likelihood of being harnessed in ten years, or even in fifty. But the energy in the nucleus of the atom is something else again. Many estimates have been prepared to show the magnitude of the world's nuclear fuel reserves (Table VI). Compared to fossil fuels, these reserves are at least twenty times as great, by even the most pessimistic estimates. So any atomic power plant has ample assurance of a continuing raw fuel supply, that is, in this country, if Uncle Sam is willing to let it have the fuel.

Many technical, legal, and economic problems remain to be solved before the nuclear plant will be competitive with other methods of generating power. But the time, talent, and money at present being devoted to the perfection of reliable and economic nuclear plants are sure to result in practical solutions. The only pertinent conjecture is, when will the goal be attained? Ten years may be too soon. But we should be close to it by 1966. Some consequences of the advent of the atomic power plant, to the civil engineer, will be:

1. There will be no fuel transportation problem, since uranium and thorium are "weightless" fuels.
2. The problem of securing water for condensing

TABLE IV.—COAL PRODUCTION AND ITS USE BY ELECTRIC UTILITY POWER PLANTS OF U. S.

Year	Total Bit. Coal production, tons	—Coal burned in utility power plants— Tons	Per-cent
1902	260,000,000	4,250,000	1.6
1912	450,000,000	12,500,000	2
1922	422,000,000	29,000,000	7
1932	310,000,000	28,000,000	9
1942	583,000,000	66,000,000	11
1947	631,000,000	90,000,000	14
1954	392,000,000	118,000,000	30
1955	465,000,000	144,000,000	31
1956*	500,000,000	150,000,000	30

* Estimated.

TABLE V.—SOURCES OF ENERGY FOR GENERATION OF ELECTRICITY IN U. S. ELECTRIC UTILITY POWER PLANTS

Year	—Percentage from— Fuel	Hydro
1922	61.2	38.8
1927	62.2	37.8
1932	58.6	41.4
1937	63.0	37.0
1942	65.6	34.4
1947	69.3	30.7
1954	77.3	22.7

Fig. 2—The trend towards outdoor power plants such as the Montrose Station of Kansas City Power & Light Co. will continue into the future and bring with it new structural, operational and maintenance problems

service will be magnified because of the poor heat rates which accompany the use of low steam pressures and temperatures, as at present planned for atomic plants.

3. In meeting containment requirements to reduce the damage from an accident to the pile, there will be structural problems—to be solved by spheres, cylinders, and underground construction.

4. Disposal of wastes and spent fuels will pose problems under conditions which dwarf the present ones of disposal of refuse from coal-burning powerhouses. Encasement of atomic wastes in concrete and burial in the ocean will not necessarily be the solution, considering the long periods of radioactivity involved and the difficulty of transporting such contaminated wastes.

Power Takes Water

The water problem is one that is certain to be of great interest to the civil engineer. While the hydroelectric plant may become of decreasing importance in the future, it must be recognized that large thermal power plants, fired by either fossil or nuclear fuels, will be faced with problems of light or variable-load operation. In regions with a hilly terrain it is believed that pumped storage may find favor. This would be economically attractive if the structures could be built at a low enough cost. Highhead sites (500 or 1,000 ft) would make for small tail and head reservoirs, and for pipelines and tunnels of small diameter. Watersheds in which the runoff is small could be utilized where only enough make-up water would be needed to compensate for evaporation and seepage losses. The idea of pumped storage is not new but its economy can be much better than formerly. Not the least of the economic factors involved is the fact that pumps can be built today with efficiencies substantially equal to those obtainable in hydraulic turbines.

The demand for water will increasingly tax the ingenuity of the engineering profession. Water is probably our most valuable resource. Those of us who live in the East often do not realize the blessing we have in our water supply. In Texas and many other parts of the country, the level of the water table is dropping at an alarming rate. In the Southwest, for example, the inadequacy of the water supply is obvious, as witness the current litigation over the remaining flow in the Colorado River. The selection of a site for a new condensing steam plant grows steadily more difficult, as witness the recent opposition of one community after another in Connecticut to the location of a new powerhouse in its area. Many areas have been compelled to use reclamation systems with towers and ponds to conserve water resources.

In most communities the restrictive regulations on the use of water grow steadily more severe. The trend toward land reclamation will grow—not decrease. And with this trend stream pollution, like atmospheric pollution, will no longer be tolerated no matter how exigent or righteous the need. Stream pollution should not be limited to a definition based upon chemistry or suspended solids. It means temperature rise as well. In some regions the need to reclaim water from sewage can become very real in the future. The ingenuity of the civil engineer will be taxed to devise reliable, economic means of supplying water to industry and to homes.

Some voluble politicians and society columnists have pictured the automobile of the future as having a pellet of nuclear fuel built in at the factory so that no gasoline or diesel fuel supply will be needed subsequently. This is hard to visualize when the problems of the critical mass, the necessary shielding, the investment required,

TABLE VI.—ESTIMATED WORLD RESERVES OF FUEL ENERGY

Fuel	Energy, Btu
Fossil fuels:	
Petroleum	Less than 8×10^{18}
Natural gas	Less than 1×10^{18}
Coal	72×10^{18}
Total fossil fuels.	81×10^{18}
Fission fuels (1 to 1 breeding)	1770×10^{18}
Ratio of fission fuels to fossil fuels, 22:1	

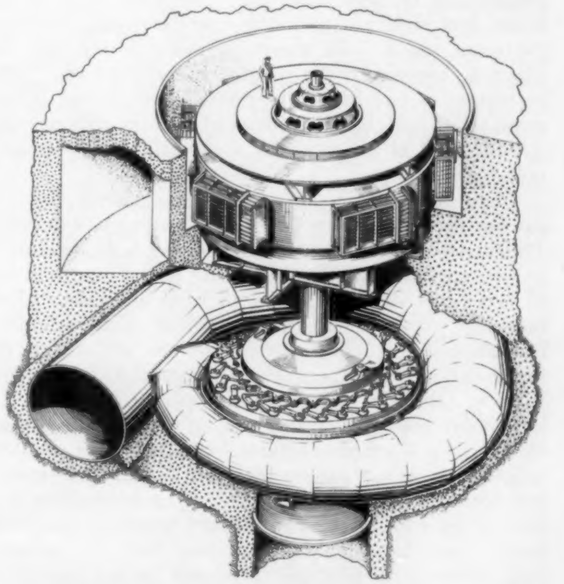


Fig. 3—Water and its availability looms large among the power engineers' problems of the future. Pumped storage, employing devices such as this pump turbine unit at the Hiwassee site on the TVA system, will find favor in hilly terrain

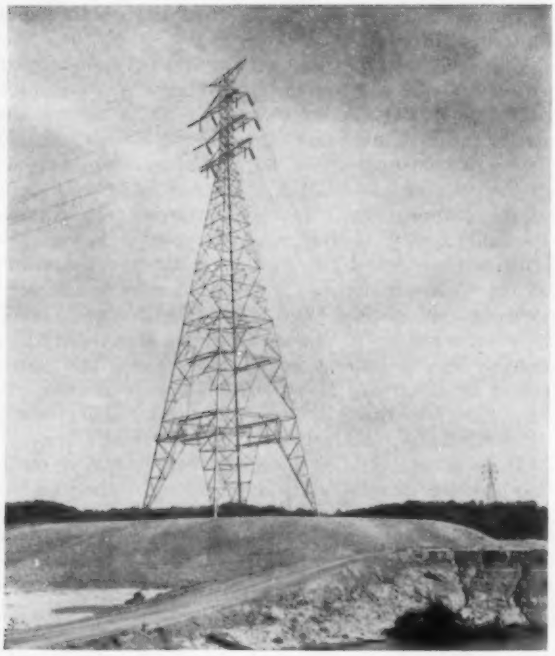


Fig. 4—In the author's opinion electricity in the future will prove so inexpensive a commodity its use will increase strongly and the problems of rights-of-way, transmission lines will be serious. These towers, 355 ft high, carry power cables 2608 ft across the Ohio River at 330 kv from Clifty Creek Station, Fig. 5, to AEC plant at Portsmouth, Ohio

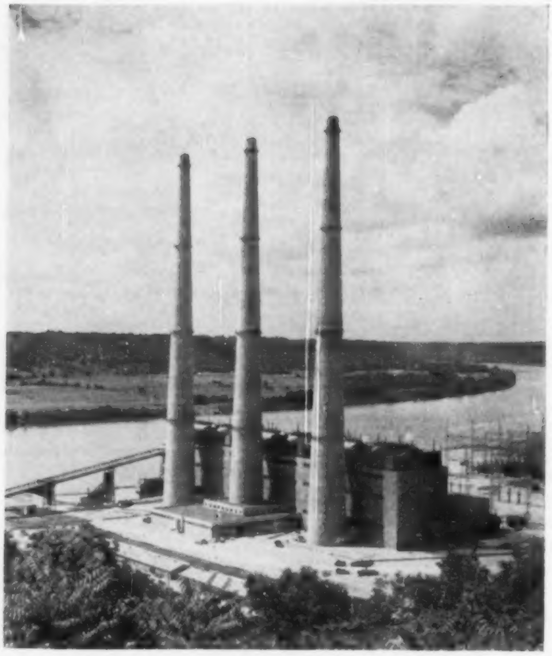


Fig. 5—Stacks topped out at 682 ft above grade for the 1,300,000-kw Clifty Creek Plant of Ohio Valley Electric Corp. point up the structural problems that confront power engineers with prospects of still larger plants in the offering

and the insurance against highway accidents are considered. There will be very few, if any, nuclear automobiles—or locomotives—in the next ten years. Liquid fuel—gasoline or distillate—will continue its domination.

For seagoing, naval, and aircraft applications, the picture can be very different. The sheer bulk of the liquid fuel required, with the ever-increasing demands for more speed, and therefore more power, can be offset by turning to the weightless nuclear fuels. The economics of pay load may retard development in the commercial field, but the enhanced military effectiveness should result in a Navy that is essentially nuclear propelled by 1966.

There are sanguine hopes in some quarters for the gas turbine and its application to automotive service. The many inducements include high-speed machinery, low weight, low bulk, high starting torque, the burning of lower-cost distillate, good thermal efficiency, fewer machine parts, no freezing problem, and minimum consumption of lubricant. These are all potent inducements for the perfection of an automotive gas-turbine. But the very low cost of the reciprocating automobile engine, as it comes from the Detroit production lines, is a serious obstacle. Similarly, the problem of a low-priced mechanism for control of the gas-turbine has not been solved. The price of the gas-turbine and that of its control are two current impediments. Research and development alone can find the answers and demonstrate whether there will be a competitive automotive gas-turbine plant in ten years.

Impact of Cheap Electricity

When the stationary nuclear power plant realizes the low cost and reliability that seem to be inherent in it, electric energy will find a market and uses that will be little short of revolutionary. Nuclear locomotives may not be realistic but electrified railways could return to economic favor using the output of stationary nuclear power plants as a source of electric energy supplied to the locomotives. Whether the development of nuclear power plants will move fast enough for this to be an actuality by 1966 is open to debate.

Should the cost of nuclear fuel become small, if not zero, the resulting changes in our industrial economy would be far-reaching. The operational and economic problems of the power plant would be similar to those of hydro-electric plants, especially the base-load type. This could serve as a tremendous impetus toward the perfection of large-capacity electric storage batteries or toward the perfection of radiation chemistry techniques, either to develop electric automobiles or to synthetize liquid fuels for motor cars. While such things probably will not happen within the next decade, the ultimate impact should be there.

It is thus possible to speculate on possible changes in railway and automotive power practices. For the civil engineer it should be evident that there will be ample supplies of energy to run the land vehicles of the future. The recently enacted federal highway legislation requires construction of projected highways that will require large supplies of building materials—cement, concrete, cinders, aggregates. The coal-burning steam power plants, which have been compelled to use lower grades of fuel over the years, are making more and more refuse which should find use in the civil engineers' store of raw materials.

The disposal of ash by direct utilization, by sintering, or by pelletizing is rapidly moving out of the laboratory stage. Ash can be expected to become a competitive building material with which construction people must reckon. Fly ash from plants using pulverized coal will not be discharged to the atmosphere as a pollutant, but will be collected and put to good use. There may be a variety of ways in which fly ash can be used but the most likely is probably as an aggregate for concrete. This use will require careful study of how to utilize the ash and still obtain the desired structural properties and strength in the finished product. This development has already reached such a stage that many people are wondering whether the supply of fly ash will be adequate for the expected market.

Growth of Air-Conditioning

Another way in which the supply of ample, cheap electric energy will change the civil engineer's outlook is in the year-round heating and cooling of living space. Not too long ago many houses were not equipped with central heating. Practicing engineers will recall that even in the city of New York, the cold-water flat is not yet extinct. Most people today demand central heating during the winter, and many have reached the stage where they will not tolerate oppressively high temperature or high humidity in summer. The demand for summer cooling is evidenced by the sale of over a million air-conditioning units each recent year.

Thus the civil engineer is confronted by the demand that space be conditioned for comfort during twelve months of the year and not just during the period from October to April. New building designs must incorporate year-round air conditioning. But the problem of the older building still remains. Such structures as the Empire State Building or the Waldorf-Astoria Hotel will not be demolished just because they lack year-round air-conditioning. In the next ten years the civil engineer will be called upon to alter such buildings, for a reasonable price, so that they will be equally habitable in summer and winter—so that they will be able to compete, on a dollar basis, with the most modern new buildings. This is a large order and it will be difficult to sell when the price tag is included.

It is reasonable to expect that the power industry will make a large contribution to the air-conditioning art. If summer cooling and winter heating are accepted as equally necessary for building space, then an abundant supply of low-priced electric energy could be the key to the solution of the problem. If the same equipment can be used for both heating and cooling then, the economic picture becomes brighter. This is the advantage of the electrically driven heat-pump. Its operation can be reversed so that it can perform throughout the year. Being electrically operated, it can be placed anywhere in the building structure. Excavations for basements are not necessary. Chimneys become obsolete—and on a tall building the chimney can be a serious problem in itself. Fuel storage tanks or fuel piles are no longer required. The ash disposal problem, the smoke nuisance, and the operating labor force dwindle or disappear when the heat-pump enters the picture.

In the next ten years the electrically driven heat-pump is bound to have a pronounced impact on civil engineers interested in the building trades. It should prove to be more economical, as well as more convenient, to transport energy electrically than to rely on central steam-heating or hot-water systems. The natural-gas pipeline will be competitive for some time but the truck delivering oil should tend to join the coal wagon in becoming obsolete.

The public will demand the convenience of a completely electrified economy, and the power engineer will be able to provide the energy at a price that will be attractive. In supplying this electric energy, the civil engineer will have to contribute his talents so as to make it possible to handle the maximum amount of energy over a given electrical transmission right-of-way. Rights-of-way are steadily growing scarcer and more expensive. This will pose a challenge to the civil engineer to design the most suitable structures on each right-of-way. It is difficult to see how underground construction, despite its esthetic appeal, can replace the overhead type. It is not unusual for subterranean construction to cost ten times as much as an overhead transmission and distribution system.

I have outlined a few of the ways in which the power engineer is going to help alter our industrial economy. All of them constitute a very definite challenge to the civil engineer. The civil engineer will be called upon to do things that heretofore have been considered uneconomical, if not unrealistic, because the power engineer is going to offer energy for stationary and transportation services at prices that cannot be ignored.

American Power Conference in Review—II

LAST month's issue of COMBUSTION carried the major portion of the American Power Conference papers held to be of value to the readers of this magazine. There were, however, so many that in the interest of space the complete meeting report was divided into two parts and the following was held over for this issue.

Water Treatment

The fourth and final water technology session concerned itself with the recent adoption of aluminum for condenser tubes. **W. A. Pollock,** technical engineer of power plants, Wisconsin Electric Power Co., opened the session with his paper "Aluminum Condenser Tubes, A Report on a Plant Installation."

As early as 1950, the consideration of aluminum tubes for condensers entered discussions with Allis-Chalmers Manufacturing Co. Nothing definite came of these discussions until 1952 when the Aluminum Co. of America, Allis-Chalmers Manufacturing Co. and Wisconsin Electric Power Co. agreed to a cooperative test program. It was decided to install a number of aluminum alloy tubes in a condenser to evaluate the resistance to steam side and water side erosion, and to determine any adverse corrosion or other conditions which might exist.

Two available locations for test were considered, one at Oak Creek where unit 1 was being erected, and the other in Port Washington, unit 5, which was in service. The latter was less desirable from the standpoint of electrolytic corrosion in that the condenser had arsenical admiralty tubes in Muntz metal tube sheets. Also, the nominal water velocity through the 26 ft-long, $^7/_8$-in diameter tubes was 8.35 ft per sec as compared with 6.95 ft per sec at Oak Creek, where the tube sheets were to be steel. In order to expedite the tests, 24 Alclad (inside) 3003-H14 alloy tubes were installed at Port Washington in July 1952.

Both plants are located on the west shore of Lake Michigan and the typical analysis of this water showed no detrimental constituents as far as aluminum is concerned.

The Port Washington trial was concluded after the 1954 inspection because a turbine outage for general inspection afforded time to make the replacement. The tubes were in good enough shape to have given several years more service despite the expected electrolytic attack at the Muntz metal tube sheets, but it was agreed to shift the test program to Oak Creek where trial tubes had already been installed in unit 1 and were being placed into unit 2, both with steel tube sheets.

For equal gage tubes the plain aluminum was found to cost one third that of admiralty, while Alclad cost 45 per cent that of admiralty per square foot of surface. The weight of aluminum tubes is about one third.

Because of the decision to change to a condenser tube made of an alloy of aluminum instead of a copper bearing alloy, used so long in the utility industry, many facets were considered aside from economics. Mr. Pollock gave some of these with conclusions, as follows:

Aluminum tubes have been found satisfactory for use in condensers under the conditions at Oak Creek Power Plant. Trial installations to determine suitability before adopting them under other dissimilar conditions are recommended, as practiced in this case.

Heat transfer characteristics for aluminum tubes are found comparable to arsenical admiralty tubes.

The economics of aluminum tubes in steel tube sheets are favorable where other conditions warrant their consideration.

Higher concentrations of aluminum are found in the boiler water and in the preboiler cycle upon starting up a new unit as compared to those existing after a substantial period of operation.

Aluminum wastage is not influenced by morpholine concentrations up to 5.8 ppm.

Ammonia due to morpholine and other sources tends to concentrate in the steam jet drains. To prevent wastage of tubes in the air cooler of the condenser the steam jet drains ought to be discarded.

R. A. Wilson, consulting engineer, Allis-Chalmers Manufacturing Co., had certain comments to pass on the Pollock paper. Among them were the following. With unfavorable water conditions aluminum tubes should be used with caution and only then after considerable experimentation has been conducted as Mr. Pollock describes. It would appear that aluminum tubes should not be used with alkali water or water containing heavy metals. It would seem prudent not to use aluminum tubes where past experience has suggested extensive acid or chemical tube cleaning.

There is an indication that there should be no formation of aluminum silicate scale in the boilers where the concentration of silica is held low such as is the practice in modern high pressure boilers.

There has beeen some fear that perhaps aluminum

tubes might foul faster than copper base alloy tubes and reduce their heat transfer values after only several years of service. However, it is felt we will have to acquire the results from several more years of operation before such theory can be substantiated. However, it appears that these fears are somewhat overemphasized especially where water conditions have been determined as satisfactory for aluminum tubes.

Ellis D. Verink, Jr., Aluminum Co. of America, also commented on the Pollock paper. Water-formed scale, Mr. Verink remarked, has been removed from aluminum tubes in chemical, petroleum and food plants by using inhibited acid cleaners. Reasonable care must be exercised to avoid damage to paint coatings or pickup of heavy metals in the cleaning solution as the result of the action of the acid on copper-base alloy parts. Heavy metal ions so picked up could plate out on aluminum or steel surfaces and stimulate localized corrosion.

At Alcoa's Rockdale Works in Texas the Industrial Generating Company, a subsidiary of Texas Power & Light Co., operates Alcoa's power plant. There are three power units whose condensers have 70,000 sq ft of admiralty metal surface. Separate aluminum tanks handle condensate for each of the three units. Periodic analyses of condensate from each of the three units began in January of 1956. The initial sample showed 0.22 ppm aluminum in No. 1 condensate storage tank. Since that time, the aluminum content of the condensate has ranged between 0.01 and 0.02 ppm. The aluminum contents consistently have been as low or lower than the copper content in Unit 2 (admiralty metal condenser tubes). Recent examination of the steam drum of Unit 1 showed no evidence of analcite scale.

Steam Turbines

C. W. Elston and **J. E. Downs,** General Electric Co., in describing the "Future of the Steam Turbine Cycle" explained that the increase in size of electric power companies resulting from increased power consumption averaging about 8 per cent per year, and coupled with better integration of systems through adequate tie lines, have permitted the effective use of increasingly larger unit ratings. Equipment manufacturers generally have been successful in developing higher rated components which are more economical and more efficient than the preceding smaller components.

Thus, the average turbine size being shipped by the authors' company to electric utilities has increased from 38,000 kw in 1947 to 156,000 kw in 1957, an average increase of 15 per cent per year. The largest unit in service is the 260,000-kw unit at the River Rouge Station of the Detroit Edison Company. The largest on order are the 450,000-kw units for the Breed Station of the Indiana-Michigan Electric Co. and the Philip Sporn Plant of the Ohio Power Co.

The paper then explored the fuel savings available from higher steam conditions along with the present economic limitations on further advances, and also, the need for new ideas and developments to permit the economical application of more efficient cycles.

An extrapolation of the heat gains possible with higher steam conditions promised about only half as much gain in heat rate as has been obtained during the preceding 20 years. The authors felt it seemed appropriate to consider whether or not the large expenditure for research and development, which obviously will be necessary to realize this improvement, is justified. However, it is apparent that the fuel savings incentive for further advances in steam conditions will be present during the coming 20 years to at least as great an extent as during any past 20-year period; but higher steam conditions will gain acceptance only if they result in reliable lower cost power, and cost of power includes, of course, capital and labor costs as well as fuel costs.

The next significant step toward lower cost electric power generation through higher thermal efficiency, the authors felt, may be the use of more efficient thermodynamic cycles or alternates to the conventional cycle such as the combined steam and gas cycle.

In the foreseeable future, the steam turbine will continue to be the "work horse" for generating electric power, according to **C. D. Wilson,** Allis-Chalmers Mfg. Co., in his paper, "Advances in the Field of Large Steam Turbines." Steam turbines operating at supercritical pressures will aid in getting more energy out of the remaining fossil fuels. As the supply of fossil fuels diminishes, atomic reactors will be increasingly used with steam turbines to generate the needed electric power.

The recent large increase in the rated size of steam turbine units for new installations has created a situation where units that were considered to be quite large a few years ago are now quite commonplace. Typical of what are now considered to be medium size units, are the 100-Mw and 150-Mw tandem-compound reheat machines operating at 3600 rpm.

The low pressure exhaust blade is one of the factors that limits turbine size. That limitation has been largely overcome by using multiple exhausts to efficiently handle the large volume steam flow of the larger machines.

An example of how the exhaust blade limitation on turbine size can be overcome by increasing the number of low pressure elements is shown in triple-flow tandem reheat turbines being built in sizes ranging from 200 Mw to 250 Mw.

The number of stages of blading in the first turbine cylinder, following the high temperature reheat inlet, is kept to the minimum necessary to reduce the steam temperature at the exhaust sufficiently to permit using high-strength, moderate-temperature materials in the turbine which follows. The reheat control valves are located between the first and second turbines.

Larger 3600-rpm turbines than this can be built by cross-compounding and using more parallel flows of the same LP elements as are used on the smaller machines. The first 300-Mw, 3600/1800-rpm close-coupled turbine-generator unit is now nearing completion and will go into service later this year.

As the ratings of these machines become larger, many of the "building block" components, originally developed for the smaller machines, can be applied with minor modifications to build the larger units. In this manner, the turbine industry has been able to progress in a gradual evolution by building on past experience.

M. M. Patterson, E. V. Pollard and **W. B. Wilson,**

General Electric Co., discussed the "Economics of Higher Pressures and Temperatures for Steam Turbines in Industrial Plants." With the avowed purpose of reviewing some of the methods already being utilized, and suggesting additional ideas that could be used to reduce the cost of steam and power in industrial plants utilizing modern turbines and generators, as well as presenting data to help evaluate these methods.

In industrial plants requiring process steam as well as power, data reviewed in this paper shows that:

(1) Power can be generated with as little as one-half the fuel required in plants for power generation only.

(2) Higher initial steam conditions can be utilized to double or triple this power generation with the same process steam flow.

(3) Feedwater heating can increase this power 15 to 20 per cent.

(4) Lower steam pressure in the process system can increase this power as much as 100 per cent or more.

Power requirements in industry are increasing more rapidly than product output. A review indicates that process-type industrial turbine-generator sizes have increased from 5000 kw to 17,000 kw in the last ten years. This rapid increase in size has been a favorable factor in industrial power plant economy. For instance, it is interesting to note the large differences in power available from different sizes of noncondensing turbines. The approximate by-product power available for each 10,000 lb per hr of process steam expanded from 600 psig, 750 F to 50 psig, pictured by the authors in tabular form, showed a rise in efficiency on the amount of by-product power that can be generated with increased unit size.

The authors then moved into a discussion of details supplemented with some excellent performance curves and tabulated data. Among the items so treated were effect of initial pressure, effect of initial temperature, fuel chargeable to power, use of automatic extraction, effect of process pressure, feedwater heating, and certain cost material for industrial plant applications.

Boiler Feed Pumps

As a part of a combined session discussing condenser and feedwater circuits two interesting papers on boiler feed pumps were presented. The first by **Igor J. Karassik** and **T. W. Edwards**, Worthington Corp., was entitled "Progress Report on High Speed Boiler Feed Pumps." The heart of this paper was the account of the studies preceding the construction of the first experimental high speed boiler feed pump and the operating record it has compiled since the Fall of 1954 when it first went into service.

High in importance among the factors contributing to boiler feed pump progress was the decision in the late twenties and early thirties to go to a 3600 rpm speed and then the later change to stainless steel construction. Both proved eminently successful. The advances from the pumps of 3600 rpm design to today's high speed pumps were prompted by these advantages:

(1) With appreciably lesser number of stages, the shaft is shorter and therefore more rigid in high speed pumps.

(2) Smaller impeller diameter gives lower casing and bolting stresses for high speed pumps.

(3) With the trend to steam turbine drive, the high speed pump is better matched to the optimum driver speed.

(4) A line of pumps divorced from the rigid limitation of 3600 rpm offers greater opportunity for standardization through speed changes, more interchangeability and a greater availability of stock parts for emergency needs.

(5) The trend to superpressure plants and the operation of boiler feed pumps at pressures from 4500 to 5500 psi makes it almost inescapable to design pumps for higher operating speeds.

In elaborating on these advantages the authors emphasized that the two prime factors affecting the life of a given high pressure boiler feed pump are the shaft deflection and the internal clearances. The greater the margin between the two, the less will be the chance of accidental contact and the longer the life of the equipment. This, higher speed designs tend to do.

The use of high speeds also tend to reduce the diameter of the individual impellers and, consequently, of the pump casing. An example of this advantage was shown by an illustration of two pumps, one high speed, one 3600 rpm, each designed to handle 3600 gpm against a discharge pressure of 4500 psi. An appreciable reduction in casing diameters and in the number and size of the bolts at the discharge head was clearly evident.

A second paper, "Boiler Feed Pumps for 6500 psi Discharge Pressure," by **H. Hornschuch,** Ingersoll-Rand Co., gave a summary of the major development work required to design the boiler feed pumps system for the supercritical pressure steam plant of the Philadelphia Electric Co.'s plant, Eddystone No. 1.

The assignment was to deliver two million lb per hr of water at 550 F through the flow control valve at a pressure of approximately 6500 psi to the monotube boiler. Compared with present day high pressure boiler feed pumps, this means a pressure increase of more than two to one and at the same time handling a water temperature at the top limit at which experience is available. Preliminary studies were made of full capacity vs. half capacity, high speed vs. 3600 rpm, single pump for full pressure, two and three pumps in series and re-entry pumps where water at low temperature and high temperature is handled in the same casing by discharging through a heater and re-entry arrangement. Within certain limitations all of the above schemes seemed feasible from a pump design standpoint.

The system selected consists of three pumps operating in series with the low and medium pressure pumps being constant speed motor drive and the high pressure pump having a variable speed steam turbine drive. The feedwater heaters are located between the low and medium pressure pumps. Two sets of half capacity units were chosen with separate heaters for each set without interconnects between heaters.

Both the low and medium pressure pumps are of rather conventional design, having forged barrel double case construction with impellers arranged in line and axial thrust compensated by a thrust balancing device. Five and six impellers, respectively, are used for generating the head, and velocity is converted into pressure by means of vane type diffusors.

The general design of the high pressure pump unit was shown in an illustration. The hydraulic element consists of four impellers arranged in line, all impellers

having single suction. The hydraulic balancing drum arrangement compensates the axial thrust. A Kingsbury thrust bearing takes care of residual thrust during load changes.

The diffusors and other hydraulic passages are arranged in a vertically split inner casing which can be handled as an integral unit for maintenance work.

The pump barrel forming the main part of the casing assembly, subjected to the 6500 psi discharge pressure, is a solid forging of 5 per cent chrome steel (Spec. ASTM-A-336 Class F-5) having a minimum wall thickness of 9 in. The suction and discharge nozzles are forgings of the same material and are welded to the casing by an approved method.

The discharge and suction nozzles have a carbon steel extension attached by welding to avoid complications in the annealing procedure on the final field weld. The discharge head closing the casing against full discharge pressure is a forging of the same material as the barrel casing so that relative movements due to thermal expansion difference can be avoided. The thickness of the head is approximately 15 in. The stuffing box extensions attached to the casing and discharge head by bolting, and which form the retainers for the floating ring seals, are also of 5 per cent chrome forgings.

All pipe connections for the seals are located in the barrel and discharge head, making it therefore possible to remove the seal assemblies without breaking any of the high and low pressure seal system pipe connections.

In a similar vein the author discussed the main gasket joint, flange bolting, the pump rotor, the shaft seal system.

Industrial Power Practices

Howard P. Kallen, *Power* Magazine, tackled the challenging subject of "Distribution of Steam and Electrical Power Costs in an Industrial Plant." As the author mentioned early in his talk it was the intent of his paper to investigate a basis for determining the economic effect of engineering proposals with respect to the question: Shall the process be further electrified or is it more economical to install additional steam-operated equipment such as process heaters, mechanical-drive turbines?

To achieve his stated aim the author decided to analyze various possible process-steam electrical-power system arrangements with a view to establishing criteria for calculation and assignment of steam and electrical charges on a departmental basis. Hypothetical cycles, however, were used. In summation the author mentioned this paper was drawn from a thesis prepared for a Master's degree.

Gerald L. Decker, superintendent of operations, The Dow Chemical Co., opened his paper, "Incremental Efficiency Testing of Industrial Turbine Generators to Determine Valve Points, Saves Kilowatts" with the question: How many kilowatts are you losing due to valve throttling? If there are noncondensing turbines in your plant, the chances are that many kilowatts are being wasted due to turbines being loaded off valve point. The valve throttling effect is much greater on topping turbines than on condensing machines due to the relatively small isentropic Btu drop involved.

In conducting many tests to establish how the performance of his company's turbines compared with the guarantee curves, there was found to be a wide variation from test to test in the deviation from the manufacturer's curve. In order to explain why the great variation, it was decided to run an incremental efficiency test. After the first test, it was obvious that the valve throttling effect was causing the wide variation. Since the manufacturer guarantees on the basis of the average of the loop, whenever a test was at a full valve point, the test would show a deviation which was better than the guarantee curve. However, when between valve points, results might be several per cent below the curve.

At the time this incremental testing started the author's company was doing a considerable amount of work in developing a dispatching system that would generate the maximum amount of power with the existing steam base. This steam base was determined by the process steam demands. The looped curves developed by the incremental testing procedure completely changed the dispatching procedure which had been based on smooth curves and the theory of equal incremental steam rates. Mr. Decker then explained the test procedure and the advantages of incremental testing.

Aaron D. Brooks, The Dow Chemical Co., followed up Mr. Decker's talk with "Precision Valve Point Loading of Turbines Using a Digital Computer Saves Dollars," which pointed out the advantages from such a dispatching system. The reasoning based on the findings Mr. Decker had explained was that if all paralleled turbines are loaded on selected valve points except for one turbine free to move under governor control to meet smaller variations in steam demands, maximum efficiency in power generation will result.

This paper showed that the precise loading of turbines at selected valve points determined by a digital computer, gives more power per pound of steam than would result if the same turbines were loaded at equal incremental steam rates, in accord with common practice.

In fact Mr. Brooks stated the savings in loading four topping turbines in his concern's Midland Plant at selected valve points instead of equal incremental rates averaged a conservative 1000 kw. This is equivalent to a net annual savings of over $52,000 per year in purchased power.

The fundamentals for loading condensing and noncondensing machines are the same. However, the common load for paralleled noncondensing machines is process steam demand at a given pressure level. Power is a by-product of furnishing steam to process, while power is the load and only product of condensing units.

The description the author gave of the steps in determining the most economical loading of four paralleled noncondensing turbines was held by him to be sufficiently detailed and general enough to give the basic steps in programming a similar problem for any digital computer. Other programming systems or modifications may be used to better fit particular situations.

Integrating Steam and Hydro

The hydroelectric session put on two papers by representatives of the largest electric generating systems in

the world, one private and the other publicly owned.

Walter Dreyer, vice president and chief engineer, Pacific Gas and Electric Co., in his talk, "Integrating Steam and Hydro Power in Northern and Central California, pointed out that it was in the area served by Pacific Gas and Electric Co. in northern California and that the connecting together of steam and hydro power plants first took place some 58 years ago. This typing together of hydro and steam plants demonstrated for the first time the principles that (1) advantage could be taken of the diversity which exists in stream flow at different hydroelectric plants; (2) steam generated power could be combined with hydro power to furnish continuous and reliable service; and (3) pooling of a regional demand, varying daily, seasonally, geographically, and with character of use, could result in economy because less capacity would be required to meet demands.

The company's power production system presently consists of 13 steam-electric plants having an aggregate capacity of 3,076,000 kw and 58 hydroelectric plants with a total capacity of 1,452,000 kw, a total of 4,528,000 kw in plants owned by the company. In addition to its own generation it takes into its system some 500,000 kw of hydroelectric power generated by other agencies.

Robert A. Monroe, chief design engineer, TVA, followed with his paper, "Some Factors in the Economic Generation of Power by the TVA System." The TVA system, as of June 30, 1956, included 45 hydro plants and 14 steam plants with an aggregate nameplate capacity of 9,280,000 kw. Included in this total are 13 hydro plants belonging to the Aluminum Co. of America, located on the Little Tennessee River watershed, having an aggregate capacity of 375,735 kw, and 3 hydro plants constructed by the U. S. Army Engineers on the Cumberland River with an installed capacity of 459,000 kw. These groups of plants are operated on schedules furnished by the TVA load dispatchers, and the power feeds directly into the TVA transmission network.

Interchange of power with adjacent utility systems can frequently be made to afford substantial mutual savings in cost of generation. Onpeak hydro power from TVA can be traded for offpeak steam from a utility. Sometimes low cost steam power can be purchased or sold to avoid operation of a more expensive plant. The installation of a 60,000 kw pump-turbine unit at Hiwassee in 1956 will allow conversion of low cost offpeak steam power into more valuable peak power.

The production cost in mills per kwhr for the system power generated in fiscal year 1956, including operation, maintenance, fuel, and depreciation, was as follows:

Source of Generation	Production Cost Including Depreciation Mills Per Kwhr
TVA hydro	1.06
TVA steam	2.66
Total system, including purchase	2.41

The average of 2.41 mills per kwhr at the generating plant switchboard includes operation, maintenance, fuel, depreciation, and cost of purchased power. Power delivered to the customer, must also cover losses and cost of operation of the transmission system, general overhead and allowance for return on investment.

BCR's Techno-Sales Conference

The recently concluded Annual Meeting and Techno-Sales Conference of Bituminous Coal Research, Inc., held at White Sulphur Springs, W. Va., in mid-April again supplied a status report on the progress of their Locomotive Development Committee. In addition a number of talks were given on the rôle of research in the solid fuels industry.

Coal-Fired Gas Turbine

P. R. Broadley, director of research, and **W. M. Meyer,** assistant to director of research, Locomotive Development Committee, recalled that late in 1955 the Committee approved plans for modifying the locomotive coal system, as well as partially reblading the gas turbine rotor. The 1955 tests were run with the bin and feeder coal system originally installed in 1951 to handle run of mine coal. The system handled $^3/_8$-in. and $^3/_{16}$-in. × 0 coals without difficulty, but it was unduly complicated, heavy, and expensive. In addition, about 15 per cent of the finest pulverized coal was vented in the air discharged from the collectors.

The development of a new fuel system to handle specification coal as a "fluid" on a locomotive has been accomplished and is presently being used in operating the turbine tests at Dunkirk. In this system, $^3/_{16}$-in. × 0 dried coal flows from aerated tanks without need for mechanical conveyors. This crushed coal is delivered by a rotary pump into the conveying air which carries it through the pressurized unit pulverizer to the combustors.

An active test program has been carried out during 1956 designed to improve the reliability and efficiency of the Dunlab separator tube. Considerable progress has been made and the present system has been altered to include improvements and refinements resulting from the tests.

Throughout the first 325 hours of operations it has been possible to make an internal examination of the third row stator and the third and fourth row rotor blades. There is indication that the dust is no longer concentrating at the roots of the rotor blades. Patterns on the concave and convex sides indicate that the gas pressures are uniformly distributed and it is hoped that the alterations made in the rotor blading are having the desired effect.

No definite evaluation can be made until after the 1000 hours have been run. When this is completed a formal report will be made by the Operations Committee to the Locomotive Development Committee and decision as to future activities will then be made.

Studies are currently under way to determine the feasibility and applications of the direct-fired coal-burning gas turbine in conjunction with and supplementary to supercharged boiler generator plants.

John W. Igoe, assistant director, Administration, followed up the above report with a discussion of "Potential for the Coal-Burning Gas Turbine." There are, according to Mr. Igoe, 3036 non-utility power-generating plants in the United States, of which 2654 are steam plants and 382 are internal combustion plants. If these plants were all to use coal-fired gas turbines, they would consume more than 110,000,000 tons of coal per year.

Three years ago Alco Products, Inc., knowing of BCR's interest in the coal-burning gas turbine, requested BCR to study the potential of the coal-burning gas turbine for stationary plant application, under Alco's sponsorship. Eventually, BCR's General Research Program became a co-sponsor. The objective of the study was to evaluate the commercial market potential of coal-burning gas turbines for stationary plants by industry and by state. The results of that study are the basis of Mr. Igoe's paper.

Of the 3036 total privately owned power generating plants previously mentioned, 1454 are 1000 kw capacity or smaller, 587 are between 1000 and 3000 kw, 279 plants are between 3000 and 6000 kw, 160 more plants are in the range of 7000 to 9000 kw, and 123 plants require from 9500 to 12,000 kw.

The point of this series of numbers, from Mr. Igoe's viewpoint, is simply that more than two-thirds of the total number of privately owned electric generating plants are in the range of the coal-burning gas turbine as developed, or in a reasonable number of multiple units. Naturally, whether such would be served by individual plants or multiple units of any particular size would be the result of an engineering and economic evaluation for the particular application.

Research

Joseph W. Barker, chairman of the board, Research Corp., in his talk, "Research—The Window on Tomorrow," put the general picture this way. The total research activity—including basic, applied, and developmental—can be linked to a huge reservoir. Pumping into this reservoir of scientific and technological knowledge are the basic research programs conducted by pure scientists supported by the universities, foundations, governmental, and, to a lesser degree, industry-wide and individual company research organizations. Classifying and sorting out of this heterogenous pool is conducted by the applied research teams of government, industry-wide and individual company organizations. Then this clarified supply is drawn down by the developmental research teams and put to specific uses in advancing technology.

Unless the general "pumping in" activities of the pure scientists are equal to or greater than the "draw down" of the development teams, technological progress will grind to a halt someday. This is the principal reason why so many have great concern that fundamental research must be generously supported by all interests who engage in the "drawing down" process. The Igoe and Rose article in the February 1957 issue of *Mining Congress Journal,* citing the "Sources of Funds for Bituminous Coal Research" as $17,382,400 for 1953, of which nearly 30 per cent came from Federal and State sources, nearly 30 per cent from "other industrial," and somewhat more than 40 per cent came from coal companies and equipment manufacturers, with only $104,000 from university, etc., sources, was extremely enlightening. Two thoughts occurred to Mr. Barker—first, is the coal industry devoting enough cents per sales dollar to research activities, particularly when one of the competing industries, petroleum, was spending $145,900,000 in the same year for research? And, secondly out of the 17 million is the coal industry allotting a reasonable proportion to the support of pure science research to assist in refilling the "reservoir" from which it is drawing?

Mr. Barker then went on to cite several examples of incidental discoveries revealed to scientists search-

ing for a specific phenomenon. The exploration of these "incidentals" such as occurs with pure research is a highly commendable activity. As such every industry should plan to sponsor some pure research.

James R. Garvey, assistant director of research, explained "The Current BCR Program" of research as one in which projects are active in all stages to provide continuous flow of developments from the initial idea to a usable product or process. Below are a few projects of interest to the power field.

Four of these projects are currently in the survey stage:

(1) Action of solvents on coal, with particular emphasis being placed on gaining information pertaining to the kinetics and mechanism of the solution of the coal substance in solvents.

(2) Increased use of coal fines. Fine coal, particularly the minus-28-mesh size, is an increasing source of loss to many producers. The trend to full seam mining plus the need for prevention of stream and air pollution have magnified the problem. Although no positive solution for this problem has as yet been developed, several methods of chemical and physical cleaning and drying of this coal size are being investigated.

(3) Controlling SO_2 emission in stack gases covering (*a*) a limited survey and evaluation of available processes for removal of sulfur dioxide from flue gases, (*b*) a continuing survey of the technical and trade journals for information on the progress and related activities of others, (*c*) bench-scale research on catalytic gas phase oxidation processes for removing sulfur-dioxide from flue gases.

The most promising available method for the removal of sulfur dioxide from flue gases is based on the wet scrubbing of the gases with ammonia solution. Progress made by various organizations in the commercial application of the process has been followed by BCR personnel through literature surveys and personal contact in both this country and abroad.

Through bench-scale tests, using sulfur dioxide in flue gas concentrations, BCR has demonstrated the removal of sulfur dioxide by catalytic gas phase oxidation. The effects of actual coal combustion gases and fly ash on the chemical and physical properties of the catalyst are currently being investigated in cooperation with an electric power utility. The ultimate objective of this research is to develop a process for the production of sulfuric acid in salable form from flue gases without requiring added raw materials.

(4) Mine acid control.

Mr. Garvey then cited some other research projects. Controlling coal plasticity for equipment design, for example, is now in the preliminary laboratory test stage. New stokers and boilers based on the cross-feed principal of burning are planned. Major advantages of this type of coal-burning are the low dust emission from the stack and the discharge of ashes in a form in which they can be readily handled automatically. However, one of the limitations to widespread application of this type of equipment is the tendency of some coals, even those considered to be free burning, to cake under certain conditions of combustion.

Similarly, in-plant pneumatic handling of coal is ready for preliminary laboratory work. One of the greatest deterrents to the more widespread use of bituminous coal in smaller commercial plants has been the difficulty and often high cost of moving the coal from the storage bin to the coal burner. While mechanical coal handling devices provide a high degree of automation, they have limitations which possibly might be

overcome through the applications of pneumatic coal handling.

Improved coal bin design as a research project is at the point where production models can undergo tests. To determine the causes and possible cures for coal flow from storage bin problems, BCR has for the past year and one-half been studying coal-flow characteristics by means of laboratory apparatus. In recent months BCR has learned how to design such bunkers to assure unassisted flow under almost any conditions of size consist, moisture content, and interrupted operation. Uninterrupted coal flow through an $8^1/_2$-in. diameter opening using $^1/_4 \times 0$-in. coal containing more than 11 per cent surface moisture has been obtained under all conditions of alternating loading and unloading the system. The results of tests of this idea have been so outstandingly successful that it is believed consideration of the use of the idea should be given in the design of all future bulk-storage bins, for coal storage or storage of other materials.

The problem of stack emission control for the commercial plant has been successfully overcome through the use of properly designed overfire jets and dust collectors. However, even though most of the large industrial plants have dust collectors which function very well under normal firing conditions, soot blowing often causes a temporary overload which cannot be completely handled by the collectors, and as a result the excess dust is carried out into the atmosphere by the flue gases. In smaller plants no dust collectors are necessary under normal operating conditions, but again during soot blowing periods stack emission is excessive. The results of recent work at BCR laboratory, in cooperation with the Diamond Power Specialty Co., showed that the use of a water spray system within the stack can alleviate this problem.

REVIEW OF NEW BOOKS

Any of the books here reviewed may be secured through Combustion Publishing Company, Inc., 200 Madison Ave., N. Y.

Reactions of Carbon with Carbon Dioxide and with Steam

By C. G. von Federsdorff

Institute of Gas Technology Research Bulletin No. 19, 76 pages, $7.50

This bulletin contains the results of ten years of study of two of the fundamental reactions in the production of manufactured gas. Studies of reactions in the temperature range of 1700 to 2500 F between a solid fuel and oxidizing gases are presented as (*a*) the development of mathematical procedures which may have general use in estimating physical and chemical factors associated with carbon gasification, and (*b*) application of these procedures to the interpretation of steam and carbon dioxide decomposition rates and gas analyses.

Most of the experimental data were obtained with continuous-flow fixed-bed reactors operating at atmospheric and superatmospheric pressures in the Institute's laboratories in Chicago. Results reported by others are analyzed in a literature study and addendum.

Design of Piping Systems

John Wiley & Sons, 365 pages, $15

A second edition of this authoritative book has been prepared by members of the engineering departments of The M. W. Kellogg Company. A complete investigation of structural design is included with emphasis on the flexibility analysis of critcal systems.

In chapters I and II, Strength and Failure of Materials and Design Assumptions, Stress Evaluation; and Design Limits, and again in the third chapter on Local Components, which treats the effect of piping reactions on local and terminal components of a piping system, there is much material to aid the designer to understand the significance of stresses in piping per-

formance. Chapter 4, Simplified Method for Flexibility Analysis, contains several newly developed approaches that facilitate the general assessment of average piping or are helpful in the planning stage of critical piping design.

Offering an unusually complete treatment of the thermal expansion problem, the new edition also gives a method for calculating the effects of uniform loading, such as that due to weight or wind. A chapter entitled Supporting, Restraining, and Bracing the Piping System covers the various problems of supporting critical piping systems, while a chapter on Vibration: Prevention and Control approaches the subject from the standpoint of the piping designer, with the objective of achieving vibration free piping in the design phase of a subject.

Other chapters deal with flexibility analysis by the general analytical methods and by model test, and approaches for reducing expansion effects. An extensive appendix includes the history and derivation of piping flexibility analysis, derivation of acoustic vibration formulas, and various charts and tables.

The engineering profession has received many benefits from the willingness of companies to share technical information, much of which was originally developed at great expense to individual organizations. This book is an outstanding example of enlightened sharing which simultaneously enhances the prestige of The M. W. Kellogg Company and greatly enriches the technical literature in the field of piping design.

ASTM Standards on Copper and Copper Alloys

ASTM, 654 pages, $5.75

All of the ASTM Standards pertaining to copper and copper alloys, which were developed by ASTM Committee B-5 on Copper and Copper Alloys, Cast and Wrought, and related standards developed by Committees B-1 on Wires for Electrical Conductors and B-2 on Non-Ferrous Metals and Alloys, have been compiled into a compact, handy volume. The December 1955 edition of ASTM Standards on Copper and Copper Alloys includes in its latest form 127 ASTM Standards—110 specifications, 12 test methods, 2 recommended practices, 2 classifications (of coppers and copper-base alloys), and 1 definition of terms.

Standards cover copper, copper-alloy, and copper-covered-steel electrical conductors; copper and copper-alloy plate, sheet, strip, and rolled bar; copper and copper-alloy rod, bar, and shapes, and die forgings; copper and copper-alloy wire; copper and copper-alloy pipe and tube; copper-alloy ingot; copper-alloy castings; copper and copper-alloy filler metal; and methods of test for copper and copper-alloys.

Of the material included in this compilation 50 of the specifications have been revised and a new specification for threadless copper pipe has been added since the previous edition.

Symposium on Atmospheric Corrosion of Non-Ferrous Metals

ASTM Special Technical Publication No. 175, 164 pages, $2.75

This symposium, which was presented at the 58th ASTM Annual Meeting in Atlantic City on June 29, 1955, covers one of the most comprehensive test programs for the measurement of atmospheric corrosion properties of non-ferrous metals and alloys every attempted. The exposure tests were started twenty-seven years ago by Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys.

The materials utilized included 24 wrought alloys of zinc, nickel, copper, lead, tin, and aluminum. These were exposed at nine significant localities across the country and evaluated after periods of 1, 3, 6, 10 and 20 years, embracing about 9000 test specimens.

The test report lists all data gleaned from these specimens and nine papers discuss in detail the significance of these results in each metals field.

Symposium on Impact Testing

ASTM Special Technical Publication No. 176, 170 pages, $3.50

In the past few years, engineers and technologists have had increasing interest in the effect of impact and shock on various materials. Both on a theoretical and practical basis, investigations have pushed forward new thinking about impact testing not confined to notch bar testing.

This symposium, sponsored by Committee E-1 on Methods of Testing at the 58th Annual Meeting in Atlantic City on June 27,1955, tries to fulfill the larger needs of this area of testing by including papers discussing impact and shock tests for parts, components and complete structures. Five additional papers considered timely and appropriate to the subject are included along with the material presented through the symposium.

Such innovations as the impact tube are discussed and environmental conditions, particularly temperature, are considered. The broad outlook is taken, so as to enhance the practical application of this type of work. The book which contains many graphs, charts and photographs, also contains several bibliographies.

New Equipment

Portable Oxygen Analyzer

The model D2, portable oxygen analyzer, has been added to the line of instruments manufactured by Arnold O. Beckman, Inc., Los Angeles, Calif. It may be used for measuring oxygen in almost any mixture of gases, and the accuracy of the reading is not affected

by other gases in the mixture. Its rugged construction is said to make it

well-suited for industrial use in such applications as excess air measurements to improve combustion efficiency. . . monitoring air leakage in inert systems . . . insuring safe entry into sewers, mines, and vessels and many other applications.

The instrument is completely self-contained and portable. Lamp current is provided by two flashlight batteries. No chemicals are used.. No special skill is needed for operation—merely squeeze a bulb to draw sample into the Analyzer, press a switch, and the oxygen concentration can be read instantly. Range is 0-25 per cent O_2. Accuracy is ± 0.5 per cent O_2.

High Volume High Pressure Fan

A new radial blade fan by Buffalo Forge Co., Buffalo, N. Y., is claimed to possess high-volume, high-pressure characteristics that make lower first cost possible on many applications. Called the *Type "CR"* Fan, it offers high mechanical efficiency—above 78 per cent over a broad range, and is also highly suitable for handling dust-laden air. These characteristics are the result of inlet-to-outlet streamlining as well as the new radial blade design. In addition to the Type CR in radial wheel type, "BR," with wider and closer-spaced blades, is a higher capacity, lower pressure type; the "DR," with narrower and deeper blades, is a higher pressure type.

Molded-Pipe Insulation

Kaytherm, a new wide-temperature-range molded-insulation designed for use on steam and heated process piping has just been introduced to the market by Keasbey & Mattison Co., Ambler, Pa., manufacturer of a complete line of asbestos products. This highly effective low conductivity insulation withstands pipe temperatures up to 1350 F. This material, produced in half-cylindrical sections and segments 36 in. long, is easy to install requiring only simple encircling metal bands to fasten two mating sections to a pipe. It can be cut easily and worked with ordinary tools, and comes in a variety of thicknesses ranging from 1 in. to 4 in. and will accomodate pipes up to 33 in. in diameter.

Business Notes

The Atomic Energy Commission has established guaranteed fair prices to be paid for plutonium and uranium-233 produced in atomic reactors operated under license in the U. S. and delivered to the Commission for the one-year period beginning July 1, 1962. The

prices are $12 per gram for plutonium metal and $15 per gram of U-233 for uranium-233 nitrate, and are based on the estimated fuel value of the materials. These prices are identical with those to be paid for these products of reactors abroad fueled with material supplied by the U. S.

Stone & Webster Engineering Corp. and *Thermal Research & Engineering Corp.* will cooperate in the promotion of a high velocity combustion method developed by Stone & Webster for producing sulfur dioxide. The joint undertaking, which shall be of special interest to the paper industry and other sulfur users, will make use of the Thermal burner in the Stone & Webster high velocity sulfur combustion process. Considerable savings in both installation and maintenance are anticipated.

A preliminary engineering study has shown that organic compounds have advantages as nuclear reactor coolant-moderators. The favorable report, which followed a five-year investigation at *Brookhaven National Laboratories* by the *Monsanto Chemical Co.*, detailed experiments using biphenyl and its compounds, with the best results being found from monoisopropylbiphenyl (MIBP).

United Conveyor Corp. has moved its general offices, engineering and development departments and laboratory to a new location at 6505 North Ridge Boulevard, Chicago 26, Ill.

A new type of steam turbine for boiler feed pumps has been designed by *General Electric Co.* to increase the amount of salable kilowatts from central power stations by as much as four per cent, and is scheduled for installation in the Glen Lyn power plant of the *Appalachian Electric Power Co.*, a part of the AGE System. The steam station is located near Roanoke, Va.

Warren Steam Pump Co., Inc., has announced that they have completed plans to open a second plant at Peace Dale, R. I., with operations scheduled to begin early this year. This new plant will be a separate division of the Warren Steam Pump Co.

Hagan Corp. has changed its name to *Hagan Chemicals & Controls, Inc.*, and at the same time its subsidiaries, Calgon, Inc., Hall Laboratories, Inc., and The Buromin Co., were merged into the parent company. Calgon and Hall will continue as divisions. The new name, it is believed, will better describe the company's activities in the fields of chemical engineering and automatic control equipment.

Gibbs & Hill, Inc., recently announced the formation of an engineering office to be located in the Wallace S. Building, 608 Tampa Street, Tampa 1, Fla. Other offices are New York Los Angeles.

245 hours less greasing time . . . 245 hours more working time EVERY YEAR!

Time saved by 1,000-hour lubrication intervals on your Allis-Chalmers tractor adds up to 245 hours every year—an extra month of production!

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For 1,000 tractor work hours, you can forget about every grease point below track level. When it's time for servicing, simple low-pressure flush lubrication replaces old grease completely, eliminates seal popping, prevents damage to seal faces. Allis-Chalmers, Construction Machinery Division, Milwaukee 1, Wisconsin.

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No. of greasings per year (5,000 hr)	up to 500	5
Greasing time (av. conditions)	½ hr	1 hr
Time spent greasing	up to 250 hr	5 hr
PRODUCTION TIME GAINED . . . 245 HOURS EVERY YEAR!		

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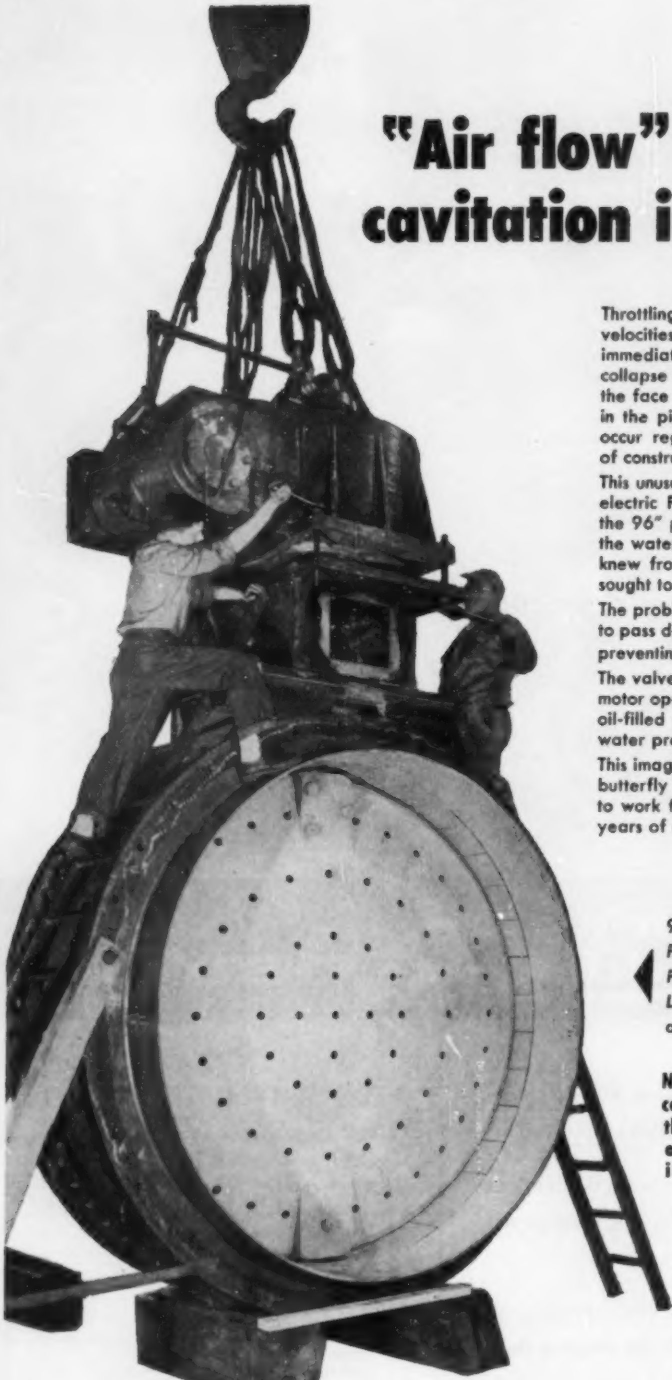
"Air flow" design prevents cavitation in Butterfly Valve



Throttling water at a high rate of flow may cause critically high velocities through the restricted area and develop a vapor pocket immediately down stream of the valve. The alternate buildup and collapse of this vapor pocket develops supernormal pressures on the face of the valve disc, accelerating erosion and causing shocks in the piping system. This phenomenon, known as cavitation, may occur regardless of the shape of the valve disc or its material of construction.

This unusual problem arose in planning the Pleasant Valley Hydro-electric Plant. Although ultimately intended for open-shut service, the 96" penstock intake valve would have to throttle flow through the waterway during the plant construction period. Pratt engineers knew from experience that cavitation would probably occur and sought to forestall damage to the valve disc and pipeline structure.

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The valve and reducer are under 65 feet of water and the electric motor operator is on a floor 68 feet above the valve centerline. An oil-filled standpipe balances pressure in the reducer with outside water pressure.

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96" valve for penstock intake at Pleasant Valley Hydro-Electric Power Plant, Los Angeles, Cal. ENGINEERS: Los Angeles Department of Water and Power.

NEW! Latest, most accurate pressure drop and flow data, conversion tables, discussion of butterfly valve theory and application plus other technical information.

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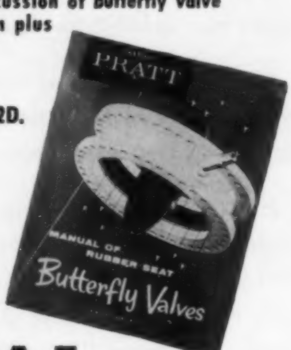

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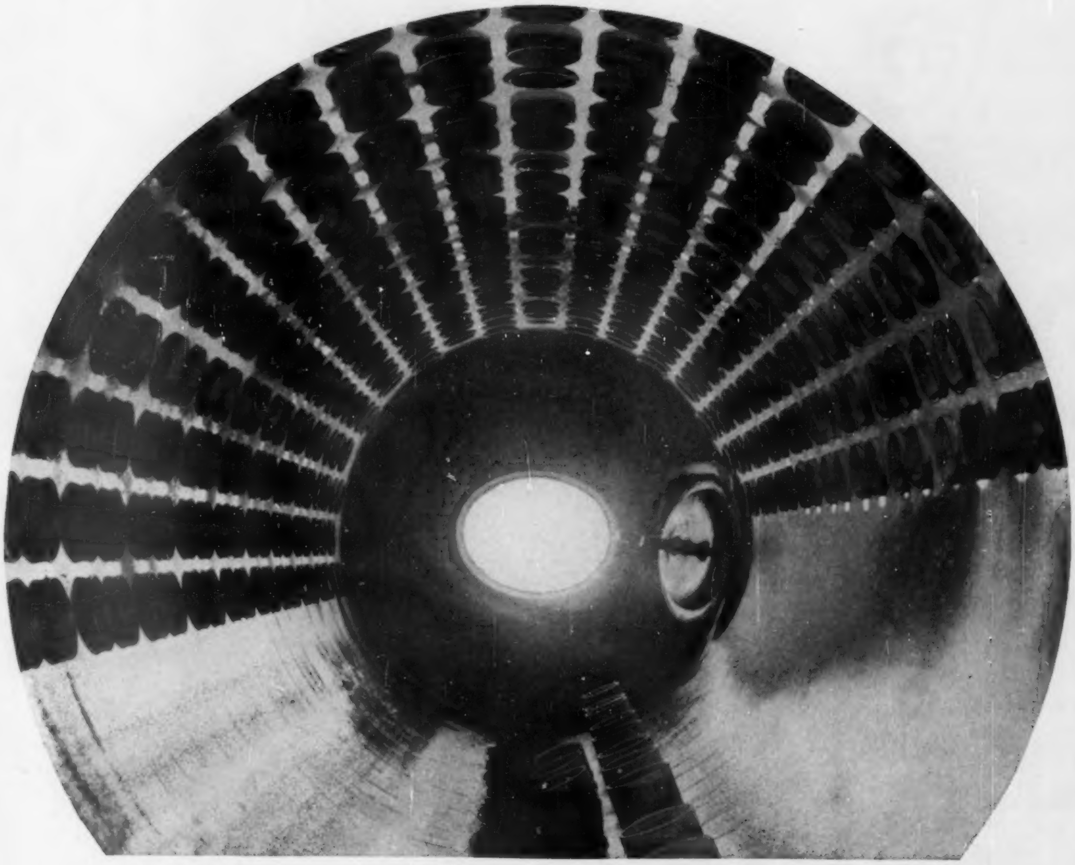

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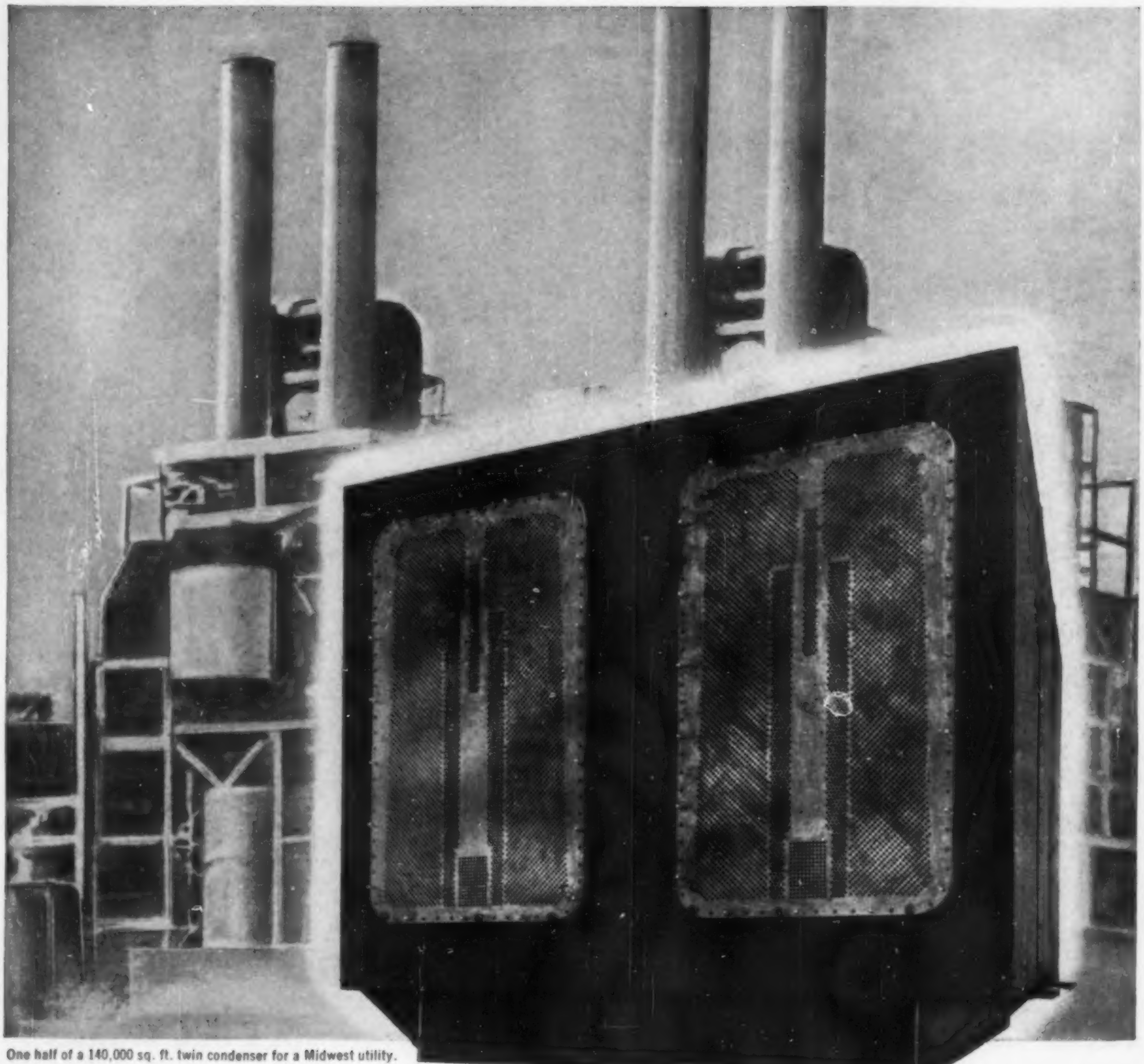

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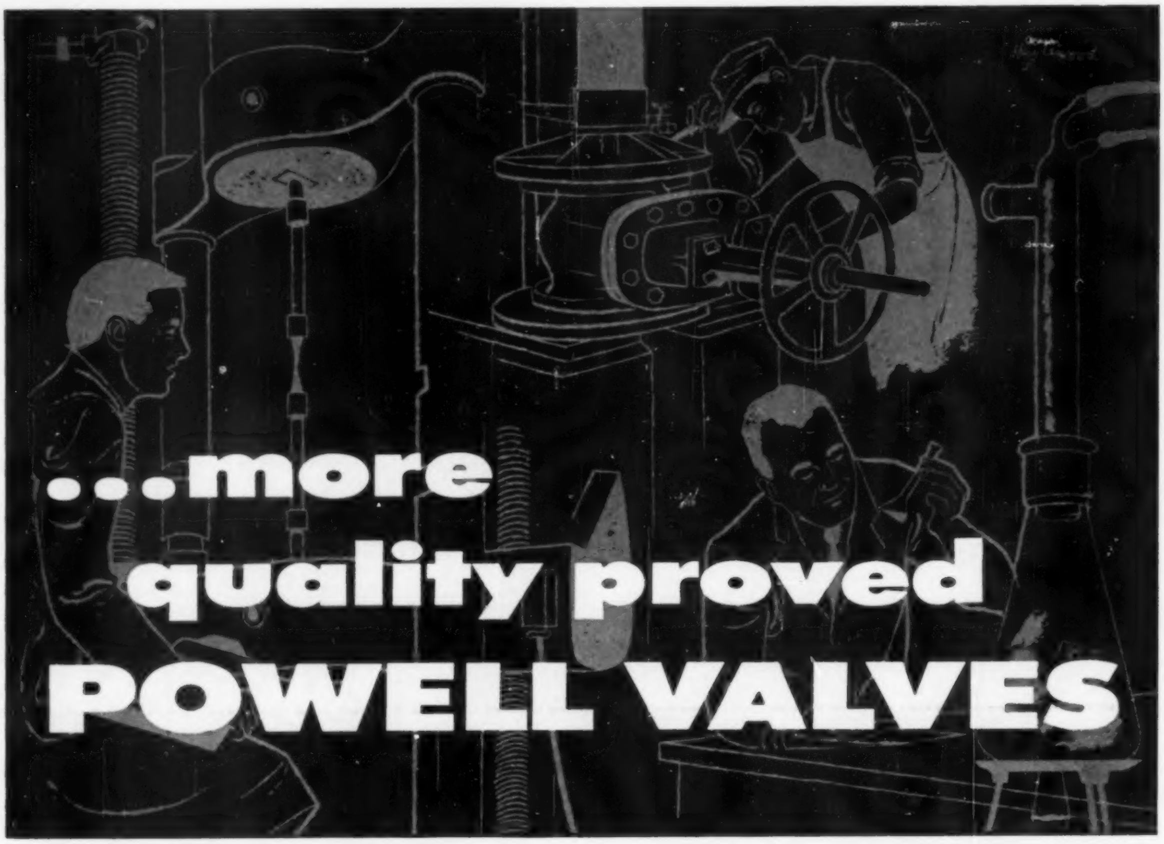


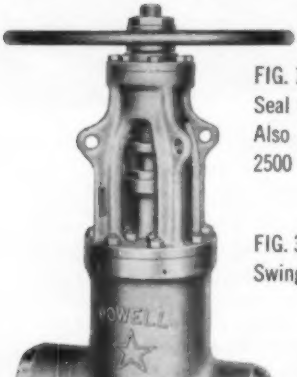
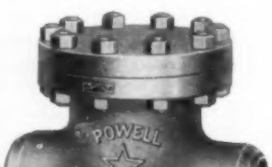


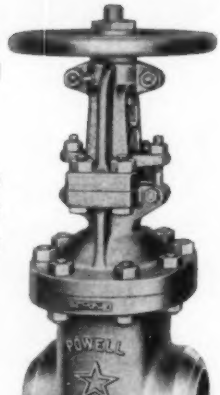
FIG. 19003 W.E.—Steel Pressure Seal Gate Valve for 900 Pounds. Also available for 600, 1500 and 2500 Pounds.

FIG. 3061 W.E.—300-Pound Steel Swing Check Valve.

FIG. 1503 W.E.—150-Pound Steel O.S. & Y. Gate Valve.

FIG. 11365 W.E.—Steel Pressure Seal Horizontal Lift Valve for 1500 Pounds. 900-Pound Valves also available.





for dependable flow control

Consult your Powell Valve distributor for full facts about quality proved bronze, iron, steel and corrosion-resistant valves. For every flow control problem—there is a Powell Valve to solve it.

THE WM. POWELL COMPANY, CINCINNATI 22, OHIO . . . 111th YEAR

GAS CLEANING NEWS

Eastern Public Utility Installs Two More Koppers Electrostatic Precipitators to Remove Fly Ash

Major Utility has installed 8 Koppers Electrostatic Precipitators since 1947

YEARS of cost-saving, highly efficient performance preceded this latest installation of Koppers Electrostatic Precipitators. During these years, this leading Eastern public utility was able to judge Koppers by on-the-job operation—the most positive proof of performance.

Proves Performance on the Job

Ten years ago, this company purchased its first two Koppers Electrostatic Precipitators for fly ash removal. Satisfactory performance and low maintenance costs justified the purchase of additional Koppers units that were installed in a total of 4 stations. The eight units furnish highly effective, trouble-free operation in a varying range of CFM capacities.

Supplies a Wide Range

The eight Koppers Electrostatic Precipitators serve boilers ranging in capacity from 570,000 #/hr to 950,000 #/hr. Guaranteed efficiency runs as high as 98%, depending on the need of each application. This ability to engineer for a wide range of capacities enables Koppers to satisfy the needs of each station.

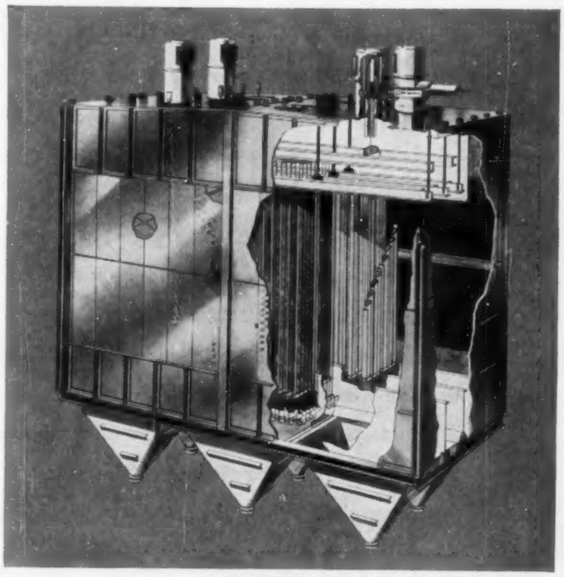
Meets Individual Plant Needs

Koppers custom-designs each Electrostatic Precipitator. Koppers units remove boiler fly ash before the flue gas is discharged from the stack. In designing Electrostatic Precipitators, Koppers utilizes its knowledge of the characteristics of various coals, types of boilers and methods of firing.

Backed by Know-How

Koppers gas cleaning experience goes back 75 years. This experience is backed up by extensive research facilities at Verona, Pa., and Baltimore, Md. From this experience and research has come gas cleaning equipment for all sizes and types of plants.

Get the most out of your gas cleaning dollar. Write KOPPERS COMPANY, INC., Metal Products Division, Industrial Gas Cleaning Dept., 4405 Scott Street, Baltimore 3, Maryland.



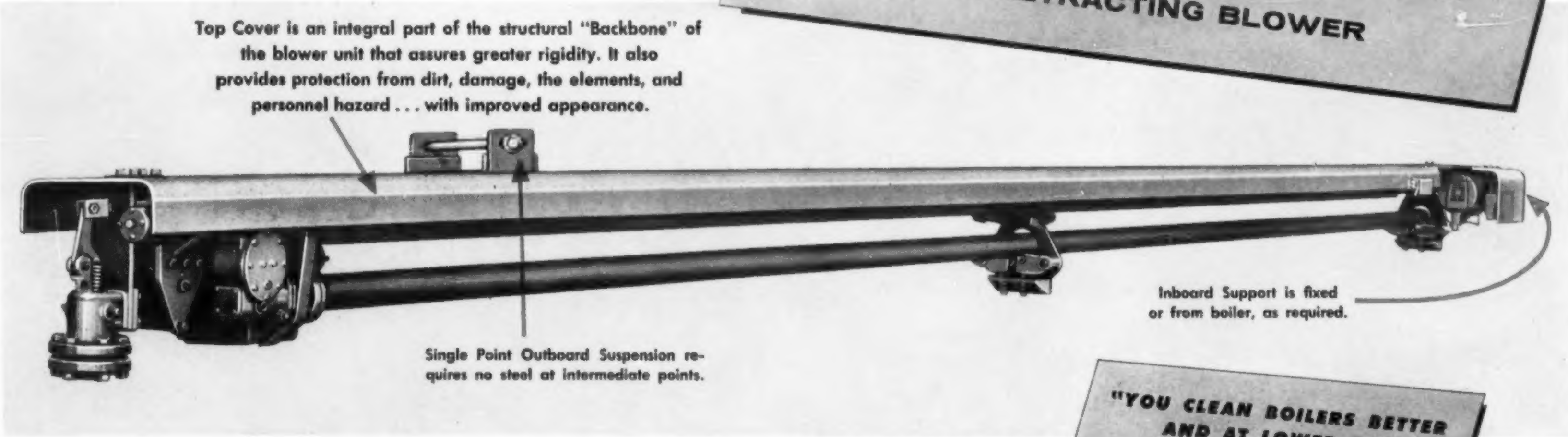
This cutaway photo of a Koppers Electrostatic Precipitator shows shell, vibrators, and collecting and discharge electrodes. The actual design and arrangement of elements vary widely because Koppers Electrostatic Precipitators are custom-engineered to fit the requirements of each installation.

Advertisers' Index

(Continued on page 83)

Backbone and Protective Cover

ANOTHER IMPORTANT FEATURE of the NEW Diamond SERIES 300 IK LONG RETRACTING BLOWER



"YOU CLEAN BOILERS BETTER AND AT LOWER COST WITH DIAMOND BLOWERS"

One of the most popular features of the new Diamond Series 300 IK Long Retracting Blower is the very substantial cover that is formed from steel plate. It is much more than just a cover in the ordinary sense . . . it is also an integral part of the structural backbone of the blower that provides maximum rigidity without excessive weight.

This is only one of many important features (see box on right hand page) of the new Series 300 IK that is establishing a new standard of efficiency, economy and dependability in cleaning those heating surfaces that require a long retracting blower. For further information about the new Series 300 IK, ask the nearest Diamond office for Bulletin 2111V.

OTHER ADVANTAGES OF SERIES 300 IK BLOWERS

- Front End Single-Motor Drive
- Compact, Accessible Electric or Air Power and Control Terminal Facilities
- Nozzle-Sweep-Every-Inch Cleaning Pattern
- Improved "Type A" Nozzle
- Positive Gear Carriage Drive
- Poppet Valve with Adjustable Pressure Control
- Positive Mechanically Operated Valve
- Single Point Outboard Suspension
- Oversize Lance (Step-Tapered for Extra Long Travel)
- Auxiliary Carriages for Extra Long Travel
- Designed for Quick, Easy Servicing

No other blower gives you all these advantages.

7671

Diamond

DIAMOND POWER SPECIALTY CORP. — Lancaster, Ohio

Diamond Specialty Limited • Windsor, Ontario

For Fly Ash Collection, here are
3,370 REASONS WHY

You're Years Ahead with MULTICLONE

The tabulation sheet shown here is over 40 feet long, filled top to bottom with single-spaced typewriter listings as shown in the enlarged section above...

- Each typewritten line tabulates an installation of Multiclone equipment—an installation of from one to nine separate Multiclone units!
- These installations have been made in all parts of the world, in plants operating under widely-varying load, atmospheric and fuel conditions!
- They include installations on virtually every type of steam power plant (i.e. pulverized coal fuel boilers, spreader stoker boilers, chain grate boilers, underfeed stoker boilers, etc.)

New Multiclone installations are being made every day, but at the time this tabulation was made there were 3,370 Multiclone units giving superior service to industry throughout the United States, Canada and other countries.

What does this mean to you? Simply this—when you select "Multiclone" you are getting equipment that has over a quarter-century of experience behind it... equipment backed by the industry's greatest fund of "know-how" in modern small tube, high-efficiency cyclonic collection. Although this unequalled experience is a part of every Multiclone installation, you pay nothing extra for this vital advantage!

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CMP Combination Units
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